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ORIGINAL ARTICLE **ÖZGÜN ARAŞTIRMA**

EVALUATION OF OPTIC NERVE SHEATH DIAMETER WITH MAGNETIC RESONANCE IMAGING AND TRANSORBITAL ULTRASONOGRAPHY

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ABSTRACT

INTRODUCTION: Our aim is to compare magnetic resonance imaging and ultrasonography and optic nerve sheath diameter measurements in critical patients who do not have a known optic nerve disease, followed in intensive care, and to find correlations or significant differences between these two methods.
METHODS: Our study was carried out prospectively observationally in the Anesthesiology and Reanimation Intensive Care Unit of TR Health Sciences University Diyarbakır Gazi Yaşargil Training and Research Hospital between May 2019 and December 2019. Critical patients aged ≥18 years, who were hospitalized in the intensive care unit, whose intracranial pressure increase was not known, and who were sedated with endotracheal intubation, ramsey sedation score 4-6, and magnetic resonance imaging were included in this study. Group 1: Optic nerve sheath diameter of 65 patients were measured by transorbital ultrasonography. 65 patients were included in the study. Group 2: Optic nerve sheath diameter of 65 patients were measured by magnetic resonance imaging method.
RESULTS: When the optic nerve sheath diameters measured with ultrasonography and magnetic resonance imaging were divided into two groups, the mean of the optic nerve sheath diameter measurements in Group 1 was found to be statistically significantly lower than that of Group 2 ($p = 0.016$). When the relationship between ultrasonography-optic nerve sheath diameter measurements and magnetic resonance imaging-optic nerve sheath diameter measurements was examined by correlation tests, there was a statistically significant very high positive correlation between ultrasonography-optic nerve sheath diameter and magnetic resonance imaging-optic nerve sheath diameter ($r=0.811$, $p<0.001$).
DISCUSSION AND CONCLUSION: The values obtained as a result of optic nerve sheath diameter measurements with magnetic resonance imaging and transorbital ultrasonography methods are correlated with each other and can be used interchangeably.
Keywords: Magnetic resonance imaging, trans bulber ultrasonography, optic nerve sheath diameter.

MANYETİK REZONANS GÖRÜNTÜLEME VE TRANSORBİTAL ULTRASONOGRAFİ İLE OPTİK SİNİR KILIF ÇAPININ DEĞERLENDİRİLMESİ

ÖZ

GİRİŞ ve AMAÇ: Amacımız bilinen optik sinir hastalığı olmayan, yoğun bakımda takip edilen kritik hastalarda manyetik rezonans görüntüleme ve ultrasonografiyle optik sinir kılıf çapı ölçümlerini karşılaştırmak ve bu iki yöntem arasındaki korelasyonları veya anlamlı farklılıkları bulmaktır.

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YÖNTEM ve GEREÇLER: Çalışmamız, prospektif gözlemsel olarak Mayıs 2019-Aralık 2019 tarihleri arasında TC Sağlık Bilimleri Üniversitesi Diyarbakır Gazi Yaşargil Eğitim ve Araştırma Hastanesi Anesteziyoloji ve Reanimasyon yoğun bakım ünitesinde yapıldı. Yaş ≥18 yıl, yoğun bakım ünitesinde yatan, intrakranial basınç artışı olup olmadığı bilinmeyen, endotrakeal olarak entübe, ramsey sedasyon skoru 4-6 olacak şekilde sedasyon sağlanan ve manyetik rezonans görüntüleme yapılan kritik hastalar bu çalışmaya dahil edildi. Çalışmaya toplam 65 hasta dahil edildi. Grup 1: 65 hastanın optik sinir kılıf çapı transorbital ultrasonografiyleyle Grup 2: 65 hastanınki manyetik rezonans görüntüleme yöntemiyle ölçüldü.
BULGULAR: Ultrasonografi ve manyetik rezonans görüntüleme eşliğinde ölçülen optik sinir kılıf çapları iki gruba ayrılıp incelendiğinde Grup 1'deki optik sinir kılıf çapı ölçümlerinin ortalamasının Grup 2'ye göre istatistiksel olarak anlamlı bir şekilde düşük olduğu saptandı (p=0,016). Ultrasonografi-optik sinir kılıf çapı ölçümleri ile manyetik rezonans görüntüleme-optik sinir kılıf çapı ölçümleri arasındaki ilişki korelasyon testleri ile incelendiğinde ultrasonografi-optik sinir kılıf çapıyle manyetik rezonans görüntüleme-optik sinir kılıf çapı arasında istatistiksel olarak anlamlı bir şekilde çok yüksek düzeyde pozitif yönlü korelasyon olduğu saptandı (r=0,811, p<0,001).
TARTIŞMA ve SONUÇ: Manyetik rezonans görüntüleme ve transorbital ultrasonografi yöntemleriyle optik sinir kılıf çapı ölçümleri sonucu elde edilen değerler birbiriyle koreledir ve birbirlerinin yerine kullanılabilirler.
Anahtar Sözcükler: Manyetik rezonans görüntüleme, transorbital ultrasonografi, optik sinir kılıf çapı.

INTRODUCTION

Intracranial hypertension (ICH) is a critical life-threatening condition. Rapid diagnosis is of great importance for timely and effective treatment (1). Invasive methods such as lumbar puncture and ventriculostomy have conventionally been used for intracranial pressure (ICP) monitoring. However, besides being impractical, complications such as bleeding and infection are negative aspects of invasive methods (2,3).

The optic nerve sheath (ONS) shows continuity with the meninges and subarachnoid space. Therefore, changes in ICP also lead to changes in the optic nerve sheath diameter (ONSD) (4,5). The ONSD can be measured by non-invasive methods, and these measurements have been found to be correlated with invasive ICP measurements performed with different techniques (6,7). In recent years, the evaluation of the ONSD by transbulbar ultrasonography (US), computed tomography (CT) and magnetic resonance imaging (MRI) has become a useful tool for non-invasive detection of changing ICP (1). Compared to CT, absence of radiation exposure is the advantage of MRI and US (8). However, MRI is expensive, time-consuming and requires the transfer of the patient (9). Bedside US provides a simple, fast and indirect assessment of ICP without transport requirement by non-invasively measuring the ONSD (2,5). The fact that it does not require patient transport, which may endanger the life of critical and emergency patients, is a very important advantage of the ONSD measurement by US (1,4). Indeed, as documented in previous studies, the ONSD exceeding a certain threshold, measured by US, may indicate ICH (1,10–12). US can be repeated at regular intervals in order to closely monitor ICP (4).

We think that the ONSD measurement results by MRI and transorbital US are correlated with each other. Therefore, we are of the opinion that transorbital US, which can be performed non-invasively at the bedside, can be safely used in the ONSD monitoring.

The aim of this study is to compare the ONSD measurements by MRI and US in critical patients without known optic nerve diseases and followed up in the intensive care unit, and to find correlations or significant differences between these two methods.

METHODS

This prospective observational study was carried out in the Anesthesiology and Reanimation intensive care unit of University of Health Sciences, Diyarbakir Gazi Yasargil Training and Research Hospital between May 2019 and December 2019. The study was started after getting approval from the ethics committee of our hospital. (Date: 19.01.2019, Number: 257/2019). The study was carried out in accordance with the 2008 Helsinki Declaration, and written informed consent was obtained from the first-degree relatives of all patients. G-Power version 3.1.9.4 (Universität Kiel, Germany) program was used to calculate the sample size. Using one-tailed alpha error of 0.05, power of 0.80 and effect size of 0.3, the minimum number of patients to be included in the study was calculated as 64. 65 critical patients aged 18 years and older, undergoing contrast-enhanced or non-contrast-enhanced cranial MRI and followed up in our intensive care unit between the study dates were included in the study.

Inclusion criteria;

• ≥ 18 years of age

• Critical patients admitted to the intensive care unit, with unknown status of ICP increase, with endotracheal intubation, sedated to ensure a Ramsay sedation score (13) of 4-6, and undergoing MRI

Exclusion criteria;

• MRI scans that provide weak visualization of the optic nerve

• Patients without consent to participate in the study

• Enucleation of an eye, optic nerve lesions, dilation or atrophy of the optic nerve, and ischemia, hemorrhage or atrophy along the optic tract

• Patients with brain death

All patients underwent electrocardiography (ECG), pulse oximetry (SpO2) evaluation and continuous invasive arterial pressure measurement after intraarterial cannulation, using a BSM-9101K monitor (Nihon Kohden Europe GmbH, Germany).

The researchers who followed up the patients in the intensive care unit, measured transorbital ONSD by US, measured the ONSD by evaluating the MRI results, collected and evaluated the results were all different. All measurements were performed by Dr. Seyhmus Kavak, one of the radiologists of our hospital. The data were collected from the patient files and electronic medical record system of the institution. Demographic and physiological data including age, gender, body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), US-ONSD and MRI-ONSD were recorded in all patients.

Cranial MRI was performed on the patients as part of their treatment strategy. All ONSD measurements by MRI were made by the same radiologist. MRI examinations were performed using a 1.5 Tesla MRI device (Siemens Avanto, Germany). The ONSD measurements were made on T2-weighted images, in the axial plane, from the area between the dural sheaths with hypointense appearance located on the edge of the subarachnoid space with hyperintense appearance surrounding the optic nerve 3 mm behind the eyeball (4,9,14) (Figure I).

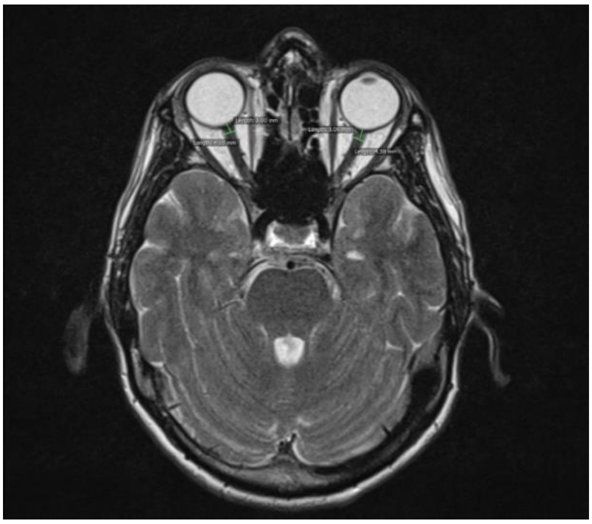


Figure I. Measurement of the optic nerve sheath diameter on T2-weighted magnetic resonance imaging.

Transorbital US was performed on the same day as MRI. All ONSD scans were performed by the primary researcher, with orbital imaging and high-resolution optimization settings, in B-mode, using a Toshiba Aplio 300 ultrasound system (Toshiba Medical Systems, Tokyo, Japan) and a 7.5 MHz linear array transducer. The patients were examined in the supine position. A probe was softly inserted into the closed upper eyelid with a thick layer of ultrasound gel. The ONSD was evaluated in the transverse plane (probe horizontally) 3 mm behind the point where the optic nerve enters the eyeball in both eyes. The distance between the outer boundaries of the hyperechoic area surrounding the optic nerve was measured in order to measure the ONSD. (Figure II) Three measurements were made for both eyes. The final binocular ONSD value for an individual was found by averaging 6 measurements to minimize variability (3,4,5,14). The ONSD values were divided into 2 groups according to the measurement method. Group 1 consisted of the ONSD values measured by US, and Group 2 consisted of the ONSD values measured by MRI.

Figure II. Measurement of the optic nerve sheath diameter by ocular ultrasonography.

Statistical Analysis: SPSS (Statistical Package for Social Sciences) 16.0 for Windows program was used for the statistical analyses. Numerical data were expressed as mean and standard deviation, while categorical data were expressed as frequency and percentage. The kurtosis and skewness tests were used to determine whether numerical data showed normal distribution. The paired t-test was used to evaluate the relationship between the groups. The Bland-Altman plot was used to determine the agreement between the two methods. The Pearson correlation test was used to evaluate the relationship between numerical data with normal distribution. Correlation coefficient (r) results were interpreted as:
No or weak correlation if r<0.2,
Weak correlation if r=0.2-0.4,
Moderate correlation if r=0.4-0.6,
High correlation if r=0.6-0.8,
Very high correlation if r > 0.8.

A p value of <0.05 was considered statistically significant.

RESULTS

A total of 65 patients, 32 females (49.2%) and 33 males (50.8%), were included in the study. The optic nerve sheath diameter measured by US was 4.53 ± 0.86 in female patients, while it was 4.48 ± 0.69 in male patients. The optic nerve sheath female patients, while it was 4.84 ± 0.74 in male patients. Demographic and clinical characteristics of the patients are shown in Table I.

When the optic nerve sheath diameters measured by US and MRI were analyzed by dividing them into two groups, the mean ONSD measurements in Group 1 (US-ONSD) was found to be statistically significantly lower compared to Group 2 (MRI-ONSD) (p = 0.016) (Table I).

Table I. Demographic and clinical characteristics of the patients.

Characteristic	Mean±SD[1]	Min-Max[2]	p[3]
Age (years)	62,43±20,61	19-95	
BMI4 (%)	26,6±5,68	17,59-41,14	
APACHE II5	27,58±7,74	8,0-45	
Peak heart rate (beat / min)	95±21,8	60-166	
Systolic blood pressure (mmHg)	127,18±23,56	69-182	
Diastolic blood pressure (mmHg)	68,1±15,7	33-120	
Mean arterial pressure (mmHg)	85,26±15,94	55-132	
ONSD by US6 (mm)	4,50±0,77	3,2-6,35	<0,001
ONSD by MRI (mm)	4,83±0,74	3,3-6,85	

[1]Mean ± standard deviation; [2]Minimum-maximum; [3]Paired t-test result (p value); [4]Body mass index; [5]Acute physiology and chronic health evaluation score; [6]Optic nerve sheath diameter.

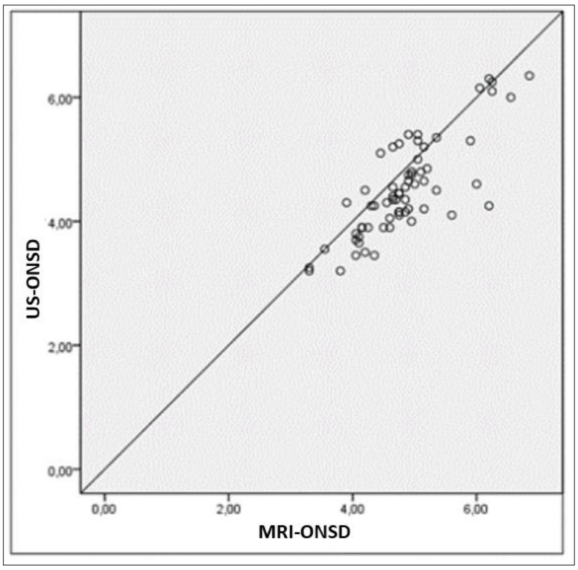
ICU admitting diagnoses and indications for MRI are shown in Table II.

When the relationship between the US-ONSD measurements and MRI-ONSD measurements was analyzed with correlation tests, it was found that there was a very high statistically significant positive correlation between these two methods (r=0.811, p<0.001) (Figure III).

In the Bland-Altman plot, the mean of the measurements was clustered in the gap between the upper and lower limits of the difference between the measurements, there was no overflow between the upper and lower limits, we interpreted this as "there was no bias in the measurements and the two methods were in agreement" (Figure IV).

DISCUSSION AND CONCLUSION

ICH causes secondary brain damage and negatively affects the patient's outcome (15). Therefore, it is of great importance to be able to monitor ICP in the intensive care unit when it is indicated. It has been shown that there is a correlation between invasive ICP measurements



Figurel III. Correlation between the optic nerve diameter measurements by US and MRI.

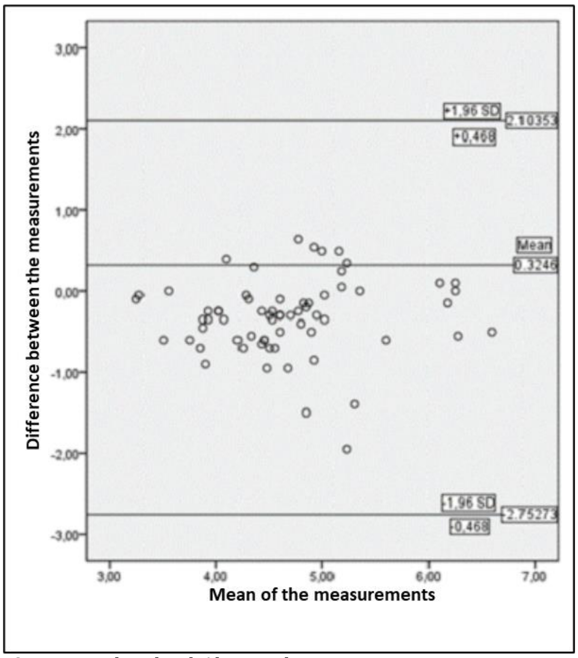


Figure IV. The Bland-Altman plot.

and non-invasive ONSD measurements using US (5,11,16,17) or MRI (18,19).

Many studies in the literature have demonstrated that the ONSD is effectively measured using MRI in various pathological conditions (18,20–22). In addition, the ONSD, which can be detected by US, has been shown to increase within seconds as a result of the increase in ICP (5,23,24). Since the eye is filled with fluid, it is ideal for US, which allows visualization of ocular structures. The orbital structure, eyeball, lens, retina and retro-ocular hematomas can all be visualized using US (2). Helmke et al. showed that pressure-related changes in the ONSD were most prominent in the bulbar segment of the optic nerve and developed a standard method in which the ONSD measurements were made by transocular US, 3 mm behind the papilla in their study (24,25).

With the development of advanced US imaging techniques, recent studies have found values ranging from an average of 4.4 to 5.4 mm for normal ONSD in adults (5,7,15,26,27). The mean ONSD differences among studies with US may be due to subtle differences in ethnicity and methodology. Variation in the angle or position of the probe or differences in resolution can constitute examples of this situation (26). The measurement accuracy is directly proportional to the power of the US probe used (28). In our study, we used a 7.5 MHz US probe with which we could provide a good enough image and found the mean value for ONSD to be 4.50 ± 0.77. Our mean US-ONSD value is compatible with the literature. Studies in the literature suggest that the ONSD measurement by US can be an effective method to evaluate ICP (5,11,16,26,29).

Although different MRI techniques (different field strength, slice orientation, slice thickness, image resolution) were used in various studies, consistent mean values between 4.7 and 5.7 mm were obtained (22,30–32). In our study, we determined the mean value for ONSD by MRI as 4.83±0.74. Our mean MRI-ONSD value is compatible with the literature. In the literature, the normal ONSD values by MRI are generally higher than those published for transorbital US (7). Lagreze et al. reported that the ONSD values measured by US were significantly lower compared to those measured by MRI. Additionally, factors such as operator experience, wrong cutting plane and limited spatial resolution of US were also assumed to be the reasons for changing results in this study (31). A major problem with transorbital US is the inappropriate angle of transmission and limited lateral spatial resolution (25). The limitations of transorbital US are decreasing with the development of high-resolution US probes (33).

In our study, in accordance with the results in the literature, the mean US-ONSD value was found to be statistically significantly lower than the mean MRI-ONSD value (p=0.016).

Recent studies have shown that a good correlation can be obtained between the ONSD measurements by US and MRI, if relevant anatomical structures are shown and measurement points are set correctly. Steinborn et al. showed a good correlation between US and MRI in the ONSD measurement in their 2 different studies on children (34) and cadavers (35). Shirodkar et al. investigated the correlation of both methods for measuring the ONSD in meningoencephalitis patients and found a good correlation between the ONSD measurements by US and MRI (4). In our study, it was found that there was a very high positive correlation between the US-ONSD and MRI-ONSD measurements (r=0.811, p<0.001).

The patients with unknown status of ICH were included in this study. The study only examined whether the measurements using the transorbital US and MRI methods were correlated with each other. This is a limitation of our study. We recommend conducting further prospective observational studies in patients who are known to have ICH.

As conclusion, in our study, we found that there was a statistically highly positive correlation between the ONSD measurements by MRI and US in the patients with unknown status of ICP increase, and the values by US were statistically significantly lower than the values measured by MRI. US can be preferred to evaluate the ONSD especially in emergency and critical patients, since it is an easy, low-cost, transport-free, risk-free, bedside-applicable and reproducible method.

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Ethics
Ethics Committee Approval: The study was approved by the TR Health Science University Gazi Yasargil Training and Research Hospital Clinical Studies Ethics Committee (Number: 257/2019, Date: 19.01.2019).
Informed Consent: It was declared that informed consent was obtained from all included cases.
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Peer-review: Internally peer-reviewed.
Authorship Contributions: Surgical and Medical Practices: CKK, OU, DK, MB, ŞK, AY. Concept: CKK, OU, DK, MB, ŞK, AY. Design: CKK, OU, DK, MB, ŞK, AY. Data Collection or Processing: CKK, OU, DK, MB, ŞK, AY. Analysis or Interpretation: CKK, OU, DK, MB, ŞK, AY. Literature Search: CKK, OU, DK, MB, ŞK, AY. Writing: CKK, OU, DK, MB, ŞK, AY.
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