



# Optic nerve ultrasonography in monitoring treatment efficacy in pediatric idiopathic intracranial hypertension

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## Abstract

**Purpose** Measurement of optic nerve sheath diameter (ONSD) with ocular ultrasonography (USG) is a noninvasive technique that can be readily used to determine clues of increased intracranial pressure. In this study, we aimed to determine the role of optic nerve sheath diameter measurements in the diagnosis and follow-up of pediatric patients with idiopathic intracranial hypertension (IIH).

**Methods** Eight patients with a diagnosis of IIH with a median age of 11.7 (range 4.5–17) years were examined prospectively. During follow-up, orbital ultrasonography (USG) was performed immediately prior to lumbar puncture (LP) and at 24 h, at 1 week, and between 1 and 18 months after LP. Cranial MRI examinations and automated visual field assessments were performed at baseline and at 3 months, and both measurements were compared with each other.

**Results** The mean cerebrospinal fluid opening pressure ( $37.75 \pm 12.64$  cm H<sub>2</sub>O) and the mean ONSD ( $5.94 \pm 0.46$  mm) were correlated. The median follow-up was 16 (range, 12–18 months), and ONSD regressed gradually consistent with clinical and radiologic improvement during follow-up.

**Conclusions** To the best of our knowledge, this is the first prospective pilot study performed on pediatric patients with IIH using orbital USG for ONSD measurements. Despite the small sample size, the present study indicated that orbital USG may be used as a promising noninvasive tool to diagnose increased intracranial pressure and for monitoring treatment efficacy in this special patient population.

**Keywords** Idiopathic intracranial hypertension · Intracranial pressure · Headache · Ocular ultrasonography · Orbital ultrasonography · Optic nerve sheath diameter

## Introduction

Idiopathic intracranial hypertension (IIH) is characterized by symptoms and signs of elevated intracranial pressure (ICP) with unclear etiology, and it is encountered in all age groups, mostly seen in young women and obese adolescents [1–3]. The diagnosis of definite IIH is based on the revised modified Dandy criteria [1]. Lumbar puncture is the gold standard for measuring opening pressure (OP) of cerebrospinal fluid (CSF) in diagnosing IIH and a commonly used therapeutic

intervention to decrease ICP [2, 4–6]. Papilledema assessment with fundoscopy, test of vision, and especially visual field using perimetry are essential tests used in adult patients with IIH to determine treatment efficacy. However, many children with IIH, especially those younger than 8 years, may not adequately cooperate during the visual field test [4]. Therefore, physicians may need additional noninvasive techniques to monitor IIH, especially in the pediatric population.

The orbital portion of the optic nerve is surrounded by dura and arachnoid maters, and CSF circulates between these two layers. Enlargement of the optic nerve sheath diameter (ONSD) reflects increased ICP, and it may be detected prior to the development of papilledema in fundoscopic examinations [7, 8]. Magnetic resonance imaging (MRI) examinations, optic coherence tomography (OCT), or orbital ultrasound may be used as noninvasive techniques to reflect ONSD enlargement in IIH [2, 8–11]. Orbital ultrasound provides an indirect assessment of ICP by measuring ONSD, and

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it has recently been commonly used in all age groups of patients with IIH [7, 8, 12, 13]. It has been shown in some adults that serial measurements of ONSD may help in monitoring treatment efficacy [14]. However, to the best of our knowledge, there is no study in the literature in which treatment efficacy has been monitored in children with IIH using optic nerve ultrasonography. The purpose of this pilot study was to evaluate the use of optic nerve ultrasonography in diagnosis and to monitor treatment efficacy in children with IIH by comparing clinical and radiologic data and the LP results of patients during an 18-month follow-up period.

## Methods

### Study population

This prospective study was performed at Gazi University Medical School, Ankara, Turkey, between May 2016 and January 2018. Pediatric patients with papilledema proven by physical examination at the ophthalmology or pediatric neurology clinics at the same university hospital were included in the study. The local ethics committee approved the study (E-17-1244); verbal and written informed consents were obtained from all patients and their families before inclusion.

### Inclusion criteria

All patients aged between 0 and 18 years, with confirmed papilledema, who had been referred to the pediatric neurology department with suspicion of intracranial hypertension were eligible and invited to participate in the study.

### Study design

The diagnosis of IIH was based on the revised modified diagnostic criteria in children [1]. The symptoms and medical histories of patients were inquired to confirm the diagnostic criteria. Detailed physical and neurologic examinations were performed. The body mass index (BMI) of each patient was noted. Obesity was defined as  $>95\%$  for weight for each age group.

Detailed ophthalmologic evaluations, cranial MRI, and MR venography (MRV) were performed before the LP procedure. Lumbar spinal tap was performed to evaluate CSF composition. Detailed blood tests were performed to diagnose secondary causes of intracranial hypertension. Increased cerebral pressure signs in MRI were evaluated by one of the authors, who was blinded to the clinical information. The signs in MRI were grouped as:

(1) Enlargement of the optic nerve sheath, which was measured at a point 5 mm posterior to the globe on an axial T2-weighted image, and it was also performed in coronal T2

sequences, which was proposed as the “target sign.” A mean ONSD greater than 5 mm was considered abnormal and meaningful for IIH.

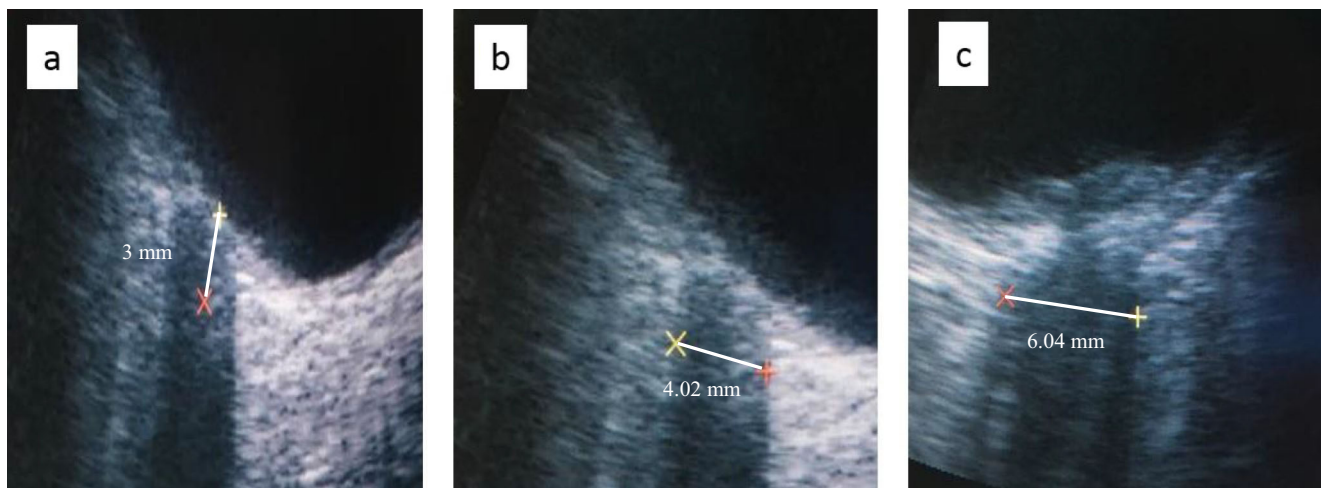
(2) Posterior globe flattening, which was described as the loss of normal curvature and straightening of the globe.

(3) Intra-orbital protrusion of the optic nerve, which was described as the concave appearance of the globe.

(4) Increased tortuosity in the optic nerve, which was described as a horizontal tortuosity of the optic nerve on an axial T2-weighted image.

The ophthalmologic evaluations including best corrected visual acuity, slit-lamp and fundus examinations, visual field assessments, B-mode orbital ultrasonography (USG) (Tomey Ultrasound A/B Scanner and Biometer UD-6000, Japanese), OCT, color fundus photography, and fundus autofluorescence (FAF) imaging were performed by the pediatric ophthalmology department before LP procedures in order to differentiate pseudopapilledema from papilledema. OCT was used for the evaluation of the optic nerve head of patients at baseline, and orbital sonography was used to monitor optic nerve sheath enlargement during the treatment period. The ONSD assessment, made using orbital ultrasonography, was performed by an experienced pediatric ophthalmologist. ONSD was measured at the bedside prior to the sedation procedure. The patients were awake and lying down in the supine position with their eyes closed. Sterile USG gel was applied to the closed eyelid; a 7.5-MHz linear ultrasonography probe was placed gently and, without pressure on the closed eyelid, paying close attention not to make any contact with the cornea or sclera. The contact with the eye was performed gently, and no pressure was directly applied on the globe. ONSD assessments were performed on axial images, which were recorded 3 mm posterior to the anterior of the optic nerve head (Fig. 1). Three measurements were obtained in each eye, and their averages were recorded. The presence of a mean ONSD of  $\geq 5$  mm was considered as enlargement. A pediatric ophthalmologist, who was blinded to LP results, patient symptoms, and was not present during LP, performed all subsequent measurements. Patients with pseudopapilledema or drusen were excluded from the study. The measurements of optic nerve sheath diameters are given in Fig. 1.

LP opening pressure was measured in the lateral decubitus position. The criteria for elevated ICP were defined as more than 25 cm H<sub>2</sub>O in nonobese patients without sedation and more than 28 cm H<sub>2</sub>O in the remainder [1, 6]. For each patient, we compared orbital USG data with LP results. Orbital USG was performed prior to LP, and serial ONSDs were performed to monitor treatment efficacy. Measurements were taken and recorded before LP, a day after the procedure, and during follow-up (first week of treatment and at months 1, 2, 3, 6, 9, 12, 15, and 18). The results of serial USG measurements were compared with the duration of the decrease on ONSD, improvement of symptoms, and papilledema detected in



**Fig. 1** Bedside optic nerve sheath diameter measurement using ocular ultrasonography. (a) Optic nerve sheath diameter (ONSD) was measured 3 mm behind the papilla (+, head of the papilla; X, 3 mm behind the papilla) in an axial plane showing the optic nerve in its longitudinal

course. (b) The normal optic nerve sheath diameter measured as 4.02 mm (the distance between two marked points). (c) The enlarged diameter of optic nerve sheath measured as 6.04 mm (the distance between two marked points) in a patient with known IIIH

monthly physical examinations. In addition, we compared the abovementioned results with ONSDs determined in follow-up MRIs at baseline and month 3.

Acetazolamide was started as a 5–10 mg/kg/day dosage and increased carefully to maximum dosage of 1000 mg/day based on clinical findings. If the patient weighed more than 50 kg, the starting dosage was 125 mg twice daily. The patients were examined carefully by a pediatric neurologist and ophthalmologist to evaluate papilledema, visual acuity, and any adverse effects of acetazolamide during each visit. Automated visual field assessments were performed at baseline and at the 1st and 3rd months of follow-up. If the 3rd month automated visual field assessment indicated an abnormality, the assessment was repeated during follow-up. The duration of medical treatment was based on all clinical findings including the resolution of papilledema, visual assessment, and an ONSD level of less than <5 mm at two sequential monthly measurements.

Baseline ONSD measurements on USG were compared with ICP, BMI, clinical findings, and ONSD on MRI. The serial measurements of ONSD on USG during the follow-up period were compared with each other. In addition, to explain the use of USG to monitor the efficacy of treatment, the degrees in diameter reduction of the optic nerve sheath were compared with baseline measurements of ONSD on USG.

### Statistical analyses

Statistical analyses were performed using the SPSS version 20.0 software (SPSS, Inc., Chicago, IL, USA). Descriptive analyses were performed, and data are presented as mean  $\pm$  standard deviation (SD). Correlation coefficient values were calculated to compare the mean ONSD and CSF opening

pressure, MRI findings, and BMI. Significance level ( $p$  value) was determined at  $\leq 0.05$  level.

### Results

We evaluated 8 children with IIIH using optic nerve USG to monitor treatment efficacy. The median age of the patients was 11.2 (range, 4.5–17) years; five (62.5%) were female. The most common symptoms were ophthalmologic symptoms as visual disturbance and diplopia (4/8; 50%). Two patients were asymptomatic, and their papilledema was detected during routine ophthalmologic examinations. Bilateral papilledema was detected in all patients. The duration of symptoms before admission was variable, ranging between 1 day and 1 year. All patients, except two, were diagnosed as having impaired visual field in the computerized visual field assessment test. In the present study, the two youngest patients could not adequately cooperate during the computerized visual field evaluation test. Detailed demographics and clinical signs are presented in Table 1.

The optic nerve sheath enlargement was diagnosed in all patients before the LP procedure using optic nerve USG. The mean ONSD immediately before the LP procedure was  $5.96 \pm 0.54$  mm in the right eye and  $5.92 \pm 0.51$  mm in the left. There was a statistically significant correlation in ultrasonographic measurements of OSDN levels between the right and left eyes ( $p < 0.05$ ,  $r = 0.952$ ). There was a positive correlation between ONSD and CSF opening pressure, but it did not reach statistical significance ( $p > 0.05$ ,  $r = 0.298$ ). The relationship between CSF opening pressure and USG measurements of mean optic nerve sheath diameter is given in Fig. 2.

**Table 1** Detailed demographics and clinical signs of patients

Case No	1	2	3	4	5	6	7	8
Age, gender	10.5, M	14.5, F	12, F	4.5, F	17, M	15, F	9, M	5, F
BMI	18	23.9	23	15.1	31.4	18.9	17.9	14.8
Symptom duration	14 days	1 day	10 days	-*	7 months	1 year	10 days	-*
Complaints	VD	Diplopia, N. Abd. palsy	Diplopia, headache	None	Headache	Headache	Diplopia, VD	None
ICP (cmH <sub>2</sub> O)	33	42	32	25	55	30	27	58
Pre-LP ONSD measurement via orbital ultrasonography (mm)								
Right	5.18	6.83	5.83	5.97	5.63	6.25	5.62	6.38
Left	5.21	6.60	5.78	6.20	5.79	6.09	5.47	6.26
Treatment	A**	A	A + D***	A	A + D	A	A	A
Treatment duration (months)	5	11	8	9	9	6	12	9
Follow-up duration (months)	18	15	15	18	18	18	15	15
The final ONSD measurement via orbital ultrasonography (mm)								
Right	4.64	4.80	4.72	4.44	4.62	4.52	4.44	4.70
Left	4.58	4.76	4.69	4.56	4.48	4.44	4.38	4.62
ONSD on MRI baseline (mm)								
Right	5.50	6.20	6.56	5.60	6.20	5.15	6.20	6.70
Left	5.70	6.90	6.60	5.80	6.80	5.50	5.80	5.90
MRI findings at baseline****	T	T, P, F	T, TR, P, F	TR	T, TR, P, F	T	T, TR	T, TR, P
ONSD on MRI at 3 months								
Right	4.90	5.20	6.16	4.80	5.60	5.05	5.40	6.40
Left	4.50	5.50	5.70	4.50	5.80	5.10	5.60	5.50
MRI findings at 3rd month	None	T	TR	None	T, TR	None	None	T, TR

*BMI* body mass index, *VD* visual disturbance, *ICP* intracranial pressure; -\*: the condition was diagnosed by coincidence (i.e., without symptom)

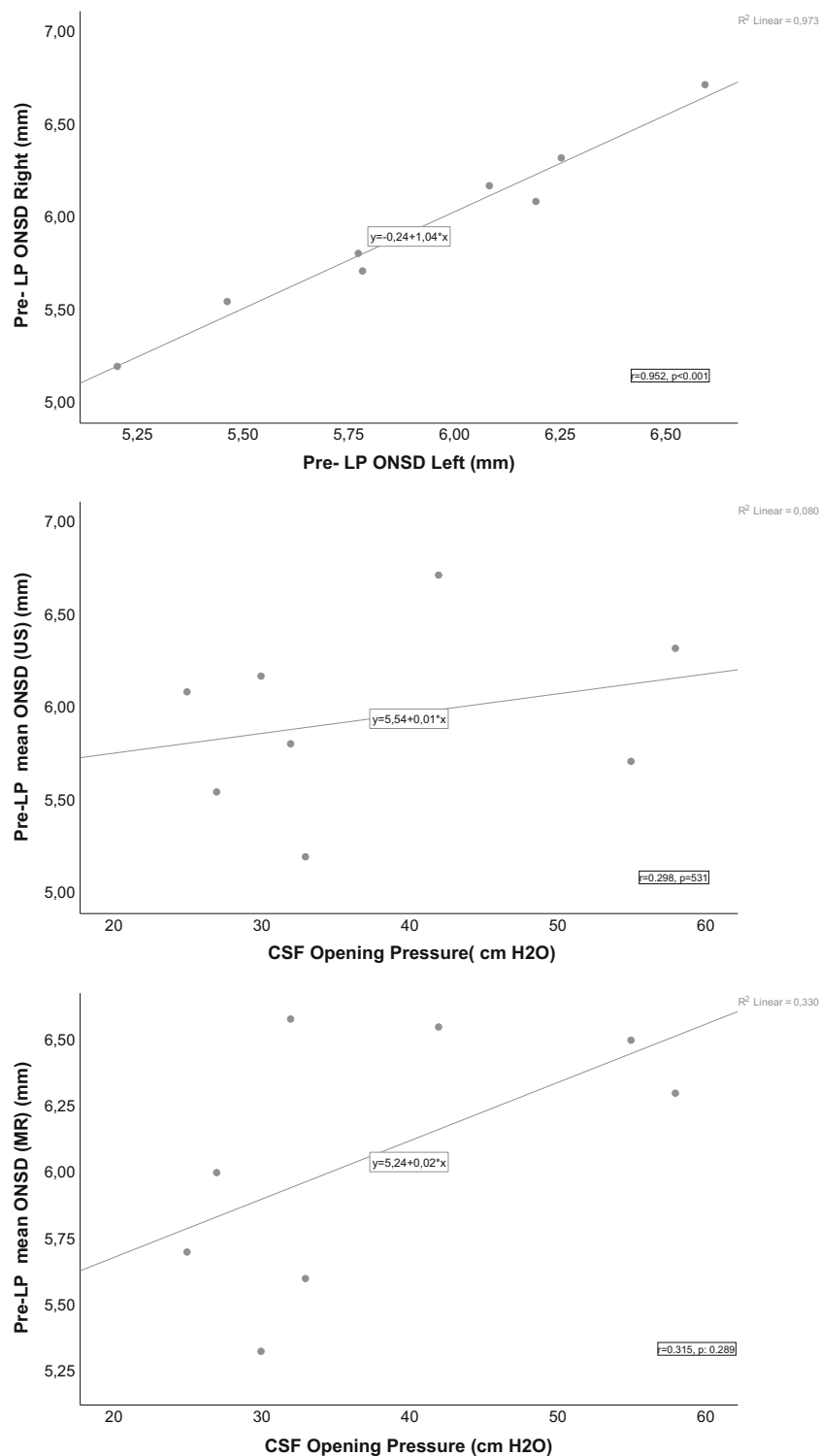
\*\*A acetazolamide treatment, \*\*\* A + D acetazolamide treatment and diet; \*\*\*\*MRI findings: *T* increased tortuosity in the optic nerve, *TR* target sign on T2-coronal slices, *P* intraocular protrusion of the optic nerve, *F* posterior globe flattening

Brain MRI revealed no intracranial mass lesion or ventricular dilation, and MRV reveal no pathology in the patients. No patients had slit-like ventricle, but one patient had empty sella. Optic nerve sheath enlargement was determined in all patients (mean ONSD values were  $6.02 \pm 0.54$  mm in the right eye and  $6.12 \pm 0.54$  mm in the left eye), and increased tortuosity of the optic nerve was determined in seven patients (82.5%). Five (62.5%) out of eight patients had the target sign on T2-coronal slices, and four (50%) out of eight had intraocular protrusion of the optic nerve. Posterior globe flattening was observed in three patients. There was a moderate, albeit statistically nonsignificant, positive correlation between CSF opening pressure and ONSD in MRI examinations ( $p > 0.05$ ,  $r = 0.315$ ). The relationship between CSF opening pressure and the measurements of mean optic nerve sheath diameter on MRI is given in Fig. 2.

The relationships between ONSD at orbital ultrasound and ONSD in MRI examinations are given in Fig. 3. According to baseline measurements, there was a positive correlation between ONSD at orbital ultrasound and

ONSD in MRI examinations, but it did not reach a statistically significant level ( $p > 0.05$ ,  $r = 0.361$ ). When the measurements at the 3rd month of treatment were evaluated, a strong correlation was found between ONSD and orbital ultrasound and ONSD in MRI examinations, but it was not accepted as a statistically significant due to level  $p$  value was found as 0.053 ( $r = 0.751$ ). Follow-up MRI examinations demonstrated regression of ONSD enlargement in all patients. The median degree in diameter reduction of the optic nerve sheath on MRI was 11.1% (range 4.7–18.4%), and the target sign and tortuosity were also observed in only three patients. Intraocular protrusion of the optic nerve and posterior globe flattening showed normalization in all patients on follow-up MRI taken at the 3rd month of treatment (Table 1).

The median follow-up duration was  $16.13 \pm 1.55$  (range, 15–18) months. All patients were treated with acetazolamide for 4–12 months, and two patients with obesity were also given a diet program. The patients' symptoms disappeared within 3–6 months, at a median of 4 months. The papilledema in fundoscopic examination disappeared within 3–7 months,

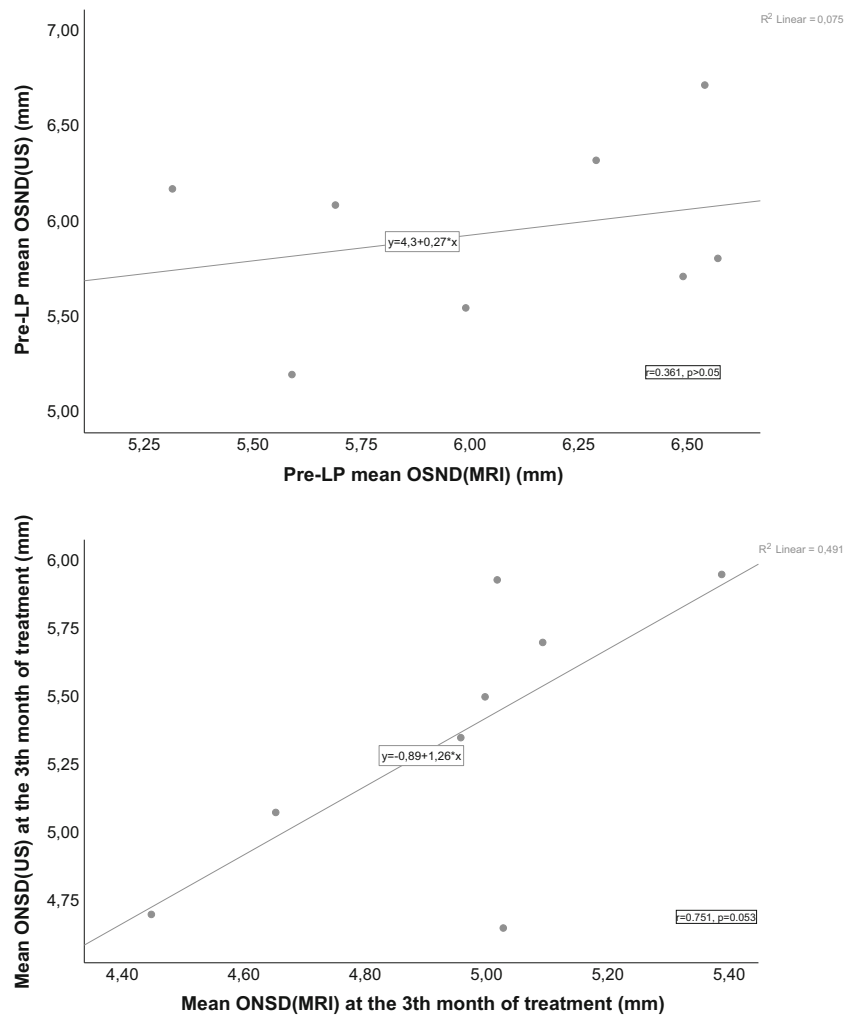


**Fig. 2** The relationship between CSF opening pressure and measurements of mean optic nerve sheath diameter by orbital ultrasound and MRI. **The first graph** shows a statistically significant correlation in ultrasonographic measurements of OSDN levels between the right and left eyes ( $p < 0.05$ ,  $r = 0.952$ ). **The second graph** shows a

positive correlation between ONSD and CSF opening pressure, but it did not reach statistical significance level ( $p > 0.05$ ,  $r = 0.298$ ). **The third graph** shows a moderate, albeit statistically nonsignificant, positive correlation between CSF opening pressure and ONSD in MRI examination ( $p > 0.05$ ,  $r = 0.315$ )

at a median of 4 months, in parallel to a reduction in ONSDs (Fig. 4). ONSD measurements gradually decreased in all

patients between 3 and 12 months, at a median of 7 months (Fig. 5). At first month of the treatment, the median degree in

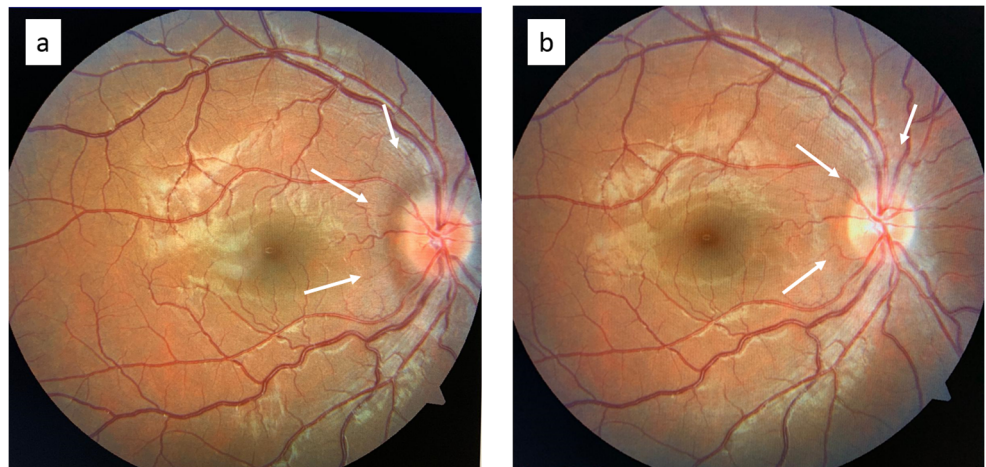


**Fig. 3** The relationships between ONSD at orbital ultrasound and ONSD in MRI examinations

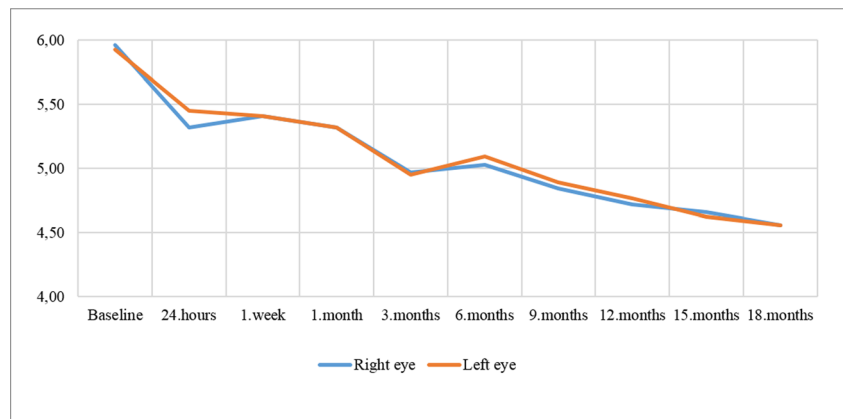
diameter reduction of the optic nerve sheath in orbital sonography was 10.2% (range, 5.1–17.4%) and 14.9% (range, 9.7–26.0%) at the 3rd month of the treatment. It reached 20.3% (range, 12.9–26.9%) at the 12th month of treatment. The mean ONSD was  $4.59 \pm 0.12$  mm at the last measurement for both

eyes in all subjects. The return of enlargement of the ONSD during follow-up was seen in two patients. None of the patients required any surgical interventions. The changes in ONSD in MRI examinations and orbital USG during the follow-up period are given in Table 2.

**Fig. 4** Colored fundus photographs. Colored fundus photographs from a fundoscopic exam of case 5 eye shows papilledema (swelling of the optic disk nerve). **(a)** Baseline assessment, arrows show papilledema; **(b)** 3rd month assessment of treatment, arrows show regression of papilledema



**Fig. 5** The changes of mean optic nerve sheath diameter



**Discussion**

To the best of our knowledge, this is the first prospective pilot study on pediatric patients with IIH to evaluate ONSD measurements using orbital USG. We found that it may be effectively used in the follow-up of pediatric patients with IIH. Although many case studies have been conducted on children aged over 12 years, there is limited information about children with IIH who are younger than 12 years [2, 4]. In the present study, we had four patients aged younger than 12 years and who had a long follow-up. Clinical presentation of pediatric IIH may vary with age; a larger number of young children may present without symptoms when compared with adolescents during routine examinations [2, 15]. In the present study, the most common symptoms were headache and blurred vision; however, two patients were asymptomatic. They were the youngest patients, and papilledema was determined during routine ophthalmological examinations.

**Table 2** The changes of measurements of optic nerve sheath diameter on MRI and orbital ultrasonography during the follow-up period

ONSD* measurements	Right eye Median (min-max)	Left eye Median (min-max)
<b>MRI results</b>		
ONSD at baseline	6.2 (5.15–6.70)	5.85 (5.50–6.90)
ONSD in month 3	5.30 (4.80–6.40)	5.50 (4.50–5.80)
<b>Optic nerve ultrasonography result</b>		
ONSD at baseline	5.90 (5.18–6.83)	5.94 (5.21–6.60)
ONSD after the LP	5.32 (4.66–5.83)	5.39 (4.74–5.87)
ONSD in week 1	5.50 (4.91–5.63)	5.46 (5.03–5.75)
ONSD in month 1	5.22 (5.00–5.56)	5.46 (5.03–5.75)
ONSD in month 3	5.05 (4.30–5.34)	4.96 (4.56–5.45)
ONSD in month 6	5.05 (4.72–5.29)	4.98 (4.83–5.40)
ONSD in month 9	4.87 (4.23–5.33)	4.88 (4.46–5.38)
ONSD in month 12	4.76 (4.48–4.91)	4.83 (4.42–4.92)
ONSD in month 15	4.70 (4.44–4.80)	4.64 (4.38–4.82)
ONSD in month 18	4.57 (4.44–4.64)	4.51 (4.44–4.58)

\* ONSD optic nerve sheath diameter

The most important complication of IIH is visual disturbance, with approximately 10–19% of patients having permanent visual disturbance [4, 6, 10, 16, 17]. Visual function monitoring is a challenge in pediatric patients with IIH. Although computerized visual field evaluation is the most convenient and practical method in adult patients with IIH, children with IIH, especially those younger than 8 years, may not cooperate adequately during testing [4]. Therefore, physicians may need additional noninvasive techniques in the follow-up of IIH, especially in the pediatric population. Increased ICP is transmitted to the optic nerve sheath, and it may lead to increased ONSD. Currently, MRI, orbital USG, autofluorescence fundus photography, and OCT are being used as noninvasive methods to detect signs of increased ICP in patients with IIH [8–10, 18, 19]. Although helpful in reaching a specific diagnosis, neuroimaging may not reveal elevated ICP at early stages of the clinical picture. Bedside measurements of ONSD have become an increasingly popular technique for patients with IIH because the method is radiation-free, and it is simple, quick, noninvasive, and sensitive with low-cost and offers indirect increased ICP monitoring [8, 19].

In the present study, the mean ONSDs were positively correlated with CSF opening pressure levels. Although ONSD enlargement and elevated ICP were correlated in pediatric and adult patients, there were some considerable differences in relevant studies regarding the cutoff values, as well as the efficacy of ultrasonographic ONSD values in ICP prediction, where values range from 4.5 to 5.9 mm [7, 8, 13]. Korber et al. measured ONSD with orbital USG in 483 patients with an age range of 4 days and 24 years [13]. They reported that the majority of patients ( $n = 466$ ) had no increased ICP, and their ONSD was  $3.4 \pm 0.7$  mm, while the ONSD was  $5.6 \pm 0.9$  mm in other patients ( $n = 17$ ) with increased ICP [13]. In another study including 51 patients, it was reported that an ONSD greater than or equal to 5 mm was associated with elevated ICP in nontraumatic causes of increased ICP; the sensitivity of  $ONSD \geq 5$  for identifying elevated ICP was 75% (95% confidence interval, 53%–90%), and the specificity was 44% (25%–65%) [20]. Major et al. assessed ONSD in 26 adult

patients, and they showed that the optimal ONSD cutoff for increased ICP was 5 mm with 86% sensitivity and 100% specificity [21]. In a prospective study, Ballantyne et al. showed that an ONSD of more than 4 mm could be considered abnormal in infants aged younger than 1 year, and a diameter of more than 4.5 mm could be considered abnormal in children aged older than 1 year [22]. Findings in a pediatric study were in line with most of the studies showing USG ONSD more than 4.5 mm in patients with increased intracranial pressure and less than 4.5 mm in patients with no increase in ICP [23]. Shuper et al. reported that ONSD values over 5 mm might be considered as definitely enlarged for children aged older than 4 years [24]. Helmke and Hansen concluded that ONSD of more than 5 mm could be considered definitely enlarged in children age over 4 years [25]. Similarly, we accepted ONSDs over 5 mm as enlarged to avoid any doubt. We found that ONSD regressed gradually during follow-up, and the mean ONSD was  $4.59 \pm 0.12$  for both eyes in all subjects at the final measurement. Therefore, all pediatric patients who have an ONSD value of  $>5$  mm may have increased ICP, for which they should be monitored closely with consideration to IIH. In the present study, there was a moderately strong, positive correlation between ONSD and CSF opening pressure, but no statistically significant correlation with MRI measurements. This outcome may be a consequence of the relatively small sample size of the present study.

Lumbar puncture is the gold standard to measure the opening pressure of CSF to diagnose IIH [1]. A wide variation of elevated ICP in the opening CSF pressure in pediatric population has been reported and measured via LP with levels ranging between 20 and 28 cm H<sub>2</sub>O [1, 6, 8]. The diagnostic criteria for IIH in adults and children were revised by Friedman et al., and elevated ICP in pediatric patients aged younger than 18 years was accepted as levels more than 25 cm H<sub>2</sub>O in nonobese patients without sedation and more than 28 cm H<sub>2</sub>O in the remainder [1]. For the present study, we used a cutoff value for ICP levels based on the abovementioned revised diagnostic criteria. In our study, the mean ICP opening pressure was 37.6 cm H<sub>2</sub>O, ranging between 25 and 58 cm H<sub>2</sub>O. Our strict inclusion criteria based on ICP levels might have led to the small sample size of our study. Although having a small sample size was a limitation of our study, we avoided possible bias regarding ICP; furthermore, the selection of revised diagnostic criteria might have contributed positively to our methodology and interpretation of our data.

Neuroimaging techniques, MRI or CT, are used to exclude other causes of IIH such as sinus venous thrombosis and cerebral mass. Several studies dealing with both adults and children showed that ONSD was significantly enlarged in patients with IIH and MR may be used to show enlargement of optic nerve sheath diameter. Although the correlation between ONSD enlargement in MRI and elevated ICP was indicated

in some studies, Inger et al. showed that neuroimaging criteria outlined in the revised Dandy criteria proposed by Friedman et al. were not useful when applied to a large population of pediatric patients with known intracranial hypertension [26]. Neuroimaging can be used to obtain indications as to whether elevated ICP is present [10, 26]. In the present study, we could not ethically justify performing LP in all subjects to confirm normal ICP and to show treatment efficacy. For this reason, we used baseline and control MRI results to compare signs of ICP and measurements of ONSD using orbital USG to show treatment efficacy in patients with IIH. The follow-up time of MRI findings was scheduled as the 3rd month because improvement of IIH symptoms was usually reported during the first 1–3 months. Although Lublinsky et al. reported quantifying response to ICP normalization in IIH via dynamic neuroimaging after the LP procedure; the average time to normalization of MRI findings of IIH has not been clearly indicated in the literature [27]. Chang et al. reported time from resolution of papilledema to MRI within a range of 8 months to 10 years [28]. In the present study, there was a moderate, albeit statistically nonsignificant, positive correlation between CSF opening pressure and ONSD in the MRIs, but all patients showed significant neuroradiologic improvements in the third month of treatment (Table 2). Although the measurements of 3rd month of the treatment between ONSD and orbital ultrasound were more correlated than baseline evaluation, it was not accepted as a statistically significant due to level *p* value was found slightly bigger than 0.05 ( $p = 0.053$ ,  $r = .751$ ). According to recent studies, MRI may also show various signs of raised ICP, such as optic nerve tortuosity, optic nerve head protrusion, target sign, and flattening of the posterior aspect of the globe [10]. However, this requires a detailed analysis of neuroimaging signs by a very experienced examiner. In the present study, follow-up by MRI examinations demonstrated regression of ONSD enlargement in all patients (Table 2). Target sign and tortuosity were also observed in only three patients, whereas intraocular protrusion of the optic nerve and posterior globe flattening showed normalization in all patients. However, our findings cannot be generalized for the use of MRI in all patients with IIH because of the small sample size.

Even though repetitive LPs are no longer recommended, they may still be required in subjects with treatment resistance and deteriorating symptoms at the time of referral or in those who develop visual field defects, which occur rarely [2, 4]. Orbital USG may help to avoid repeated LPs in these patients. In the present study, LP was used as the gold standard test to confirm and diagnose increased ICP at baseline. However, we could not ethically justify performing LP in all child subjects during the follow-up period. We used baseline and control MRI results to compare the signs of increased ICP and measurements of ONSD using orbital USG during the follow-up period. We determined that orbital USG might be used as a



valid and reliable method for longitudinal evaluation of pediatric patients with increased ICP secondary to IIH. A progressive decrease in ONSD might be reflective of a successful decrease in ICP and improving papilledema. Conversely, an increase in ONSD during follow-up might reflect increased ICP.

Recurrence of ONSD enlargement was observed in two patients during the follow-up. First patient was a 5-year-old girl who showed papilledema recurrence in the fundoscopic evaluation and recurrence of ONSD enlargement at the third month follow-up after discontinuation of acetazolamide. She could not adequately cooperate during the computerized visual field evaluation because she was young. She had no symptoms, but optic disk edema and enlargement of ONSD were worsening gradually. Therefore, follow-up LP was planned to measure ICP, but the family did not give permission. For this reason, acetazolamide treatment was readministered, and the patient was closely observed until ONSD, and optic disk edema were recovered. The other patient, being the most obese child in the sample group, had mild nonspecific headache and ONSD enlargement. He had broken down his diet program and gained almost 8 kg in a short time. He did not accept starting medication. His visual field evaluation was normal. He was followed closely, and he started a strict weight loss program under a dietitian's supervision. He lost weight, and the ONSD decreased gradually within 4 months.

Most of adult and pediatric patients with IIH respond to maximal nonoperative therapy; however, surgical intervention for IIH may be necessary in circumstances of failed medical treatment or progressive visual loss or intractable headache despite maximal medical therapy. The decision for surgical treatment depends on clinical follow-up. Despite surgical intervention, visual distribution and headache have been reported even in posttreatment patients. In the present study, orbital USG was used to monitor the efficacy of treatment in pediatric patients with IIH; the return of enlargement of the ONSD during follow-up was seen in two patients, but neither patient required any surgical intervention. Orbital USG may also be used to monitor the efficacy of treatment in pediatric patients with IIH after surgical intervention. The paper does not provide any information with regard to ONSD measurements after CSF derivative surgery because no surgical cases were encountered in the study period. A large, multicenter, prospective study including postsurgical patients may give further information.

## Study limitations

The main limitations of our study include the small sample size that resulted from our strict inclusion criteria and the lack of a control group, which would have allowed us to make comparisons between affected subjects and the normal

pediatric population. A multicenter, prospective study with a large sample size including a control group would increase the probability of obtaining further information about the use of orbital USG in diagnosing IIH and monitoring the treatment process.

## Conclusion

Lumbar puncture is the gold standard diagnostic method for IIH. Orbital USG, as a noninvasive diagnostic technique, enables indirect assessment of signs of ICP through ONSD measurements. In the present study, we demonstrated that orbital USG may be used as a noninvasive tool to show signs of increased ICP and to monitor the efficacy of treatment in pediatric patients with IIH. A large, multicenter, prospective study including postsurgical patients and a control group may give further information about the use of orbital USG in monitoring the treatment of IIH in both conservatively and surgically treated children.

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## Compliance with ethical standards

**Conflict of interest** The authors report no conflict of interest.

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