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Optic Nerve Sheath Diameter Assessment and its Association with Eyeball Transverse Diameter on 1.5T in Healthy Adults

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Abstract: ***Imaging evaluation of the anterior visual pathway, particularly the structures like optic nerves (ON) and optic nerve sheath diameter (ONSD), requires knowledge of standard dimensions. Apart from clinical and ophthalmoscopic evaluation, imaging, especially MRI, plays an essential role in the complete evaluation of optic nerve and the entire visual pathway. The ONSD has been found to have a competent correlation with intracranial pressure (ICP) can be used as an indirectmarkerof intracranial hypo or hypertension. The normal limits of ONSD as measured using T2 weighted MR imagesand its correlation with clinical parameters and the eyeball transverse Diameter (ETD) needs standardization. Our secondary objective is to deduce the ONSD assessed at different depths (3, 6, or 9 mm) and arrive at a ratio of the ONSD and eyeball transverse diameter (ETD) which are better correlated with ICP. The data serves as a baseline standard for comparison of ONSD in patients of various age groups and to further quantify the technique of measuring the ONSD.***

Keywords: Anterior visual pathway, optic nerve sheath diameter, eyeball transverse diameter

1. Introduction

The anterior visual pathway comprises of small structures, namely retina, optic nerve sheath complex (ONSC), optic chiasm (OC), and optic tract. The ONSCencompasses the optic nerve (ON) and optic nerve sheath (ONS). ON, a white matter tract of the CNS which passes via the optic canal into the orbit. It is surrounded by CSF and ensheathed by all three meningeal layers (dura, arachnoid, and pia mater), and experiences the same pressure changes as the intracranial compartment [1,2]. There is adequate evidence that the ONSD is an indirect marker of ICP, with a linear relationship between these two parameters.

A spectrum of diseases affects the size of anterior visual pathway structures.These can be broadly divided as congenital and acquired conditions, few examples include, optic neuritis, perineuritis, optic atrophy, glaucoma, optic sheath meningioma, ON glioma, and intracranial pathology, trauma and neoplasm, that causes raised intracranial pressure (ICP). Elevated intracranial pressure is also seen in, stroke, liver failure, meningo-encephalitis, idiopathic intracranial hypertension and post-resuscitation syndrome.

The dural sheath of the optic nerve distends with elevation of intracranial pressure and collapses with intracranial hypotension, makingobjective measurement of these structures is often a crucial part of the diagnostic assessmentand in the management

Even thoughspecificinvasive methods- intraventricular catheterization and intraparenchymal probes are considered as the gold standard for ICP estimation, these have limitationsowing to the risk of complications such as hemorrhage and infection, and contraindications such as severe platelet disorders or coagulopathy. These factors urged on noninvasive measurements of ICP- leading to MRI and CT, which are often performed with suspected raised Intracranial Pressure (ICP) and can be used to measure the ONSD [3]. As there is a correlation between ONSD and ICP, and MRI serves as a better tool for detecting intracranial hyper or hypotension, as that the anatomical structures and borders of the optic nerve and nerve sheaths are better delineated in MRI

2. Materials and methods

Background and the methodological considerations. We reviewed 100 participants who underwent MRI scanning of the brain, as part of comprehensive health screening at the Alluri Sitaram Raju Academy of medical sciences, Eluru, West Godavari, Andhra Pradesh, India between June 2019 and Feb 2020. Images were acquired using 1.5 Tesla MRI (seimens). Patients were positioned supine,with straight gaze, and participants were counselled before the examination to avoid eye movements during image acquisition. Images were processed on workstation and archived to the PACS.

2.1 Inclusion/exclusion criteria

In total, 100 individuals were finally included in this study. The sample population was divided into age groups of each decade of life from 10 to 80 years. Those with clinical findings of a history of ophthalmological or neurological disorders trauma to the orbit or, poor imaging quality due to

severe motion or metallic artefacts and incidentally detected intracranial pathologies that can influence ICP, intracranial neoplasms and intracranial vascular malformationsthat could reasonably affect the optic nerve diameter were excluded from the study.

Table 1: Pathologies affecting the optic nerve and optic nerve sheath

Congenital	Optic nerve aplasia Optic nerve hypoplasia Wolframs syndrome
Demyelination	MS Acute disseminated encephalomyelitis
Inflammatory	Perineuritis SLE associated optic neuritis
Ischemic	Optic neuropathy (anterior and posterior)
Neoplastic	ON glioma Metastases Optic nerve sheath meningioma
Miscellaneous	Traumatic/toxic neuropathy Idiopathic intracranial hypertension

2.2 Image evaluation

Axial T2WI source images were used to measure the ONSD and ETD of each eye.ONSD was measured at 3 mm, 6mm and 9mm behind the eyeball along an axis perpendicular to the optic nerve, ONSD is defined as distances between the outer margins of the thick sheath layers covering the optic nerve and ETD (retina to retina) as the transverse diameter of the eyeball. Intraobserver variation was limited by taking each measurement was made twice, and its mean value was obtained.

2.3 Statistical evaluation

Data were collected and recorded in customized Microsoft Excel tables.Variables are categorized as frequencies and percentages, summarized through the calculation of mean and standard error. Basic descriptive statistics (mean, SD, minimum, and maximum) were calculated for every variable.

3. Results

The total of 100 healthy adults included 64 (64%) men and 36 (36%) women. The mean age was 48 years (range: 12–80 years), 49 yearsin females and 47 years in males. Statistically no significant differences were observed between males and females. No correlation was established between age and ON measurements.

The optic nerve sheath complex diameter varied between 3.1 mm and 6.9 mm for the right eye and 3.05 mm and 7.4 mm for the left eye, with a median of 4.7 mm in both eyes. The mean ONSD was 4.8 mm. The mean values of ONSD and ETD were 4.8 mm and 21.6 mm, respectively. The ONSD did not differ significantly on comparing the right and left eyes.

Table 2: ONSD and ETD ratio measured using magnetic resonance imaging

	Mean±SD	Median	Minimum	Maximum
ONSD (mm)				
Right	4.8±0.78 (4.02–5.58)	5	3.1	6.9
Left	4.9±0.94 (4–5.8)	4.9	3.05	7.4
Overall	4.85±0.86 (4–5.7)	4.9	3.05	7.4
ETD (mm)				
Right	21.5±0.8 (20.7–22)	21.4	20.02	23.8
Left	21.8±0.8 (21–22.6)	21.5	20.13	23.8
Overall	21.7±0.9 (20.8–22.6)	21.45	20.02	23.8

The overall value is the value for the left and right eyes combined.

ETD: eyeball transverse Diameter, ONSD: optic nerve sheath diameter, SD: standard deviation

We studied ONSD not just at 3 mm beyond the eyeball but also at 6 and 9 mm because of studies showing an association between ICP and ONSD at depths beyond 3 mm. The theory here for measuring an ONSD farther from the eyeball is that the dural and scleral attachments may limit ONSD expansion with increasing elevations in ICP and ONSD tends to decrease bilaterally as the depth is increased. Similarly, the ratio of ONSD/ETD also decreases. There was functionalparallelism in values for both ONSD and ETD between the right and left sides. A possible downfall of using ONSD measurements alone is the difference in the size of the eyeball from case to case. The ratio of ONSD/ETD is aimed to find a useful parameter which is sensitive and specific for ICP assessment and mainly to account for the normal variability in globe phenotype [4, 5] Our study, however, showed a decrease in the ONSD beyond the globe at 6mm and 9mm in the majority of the cases. We further determined normative values for the MRI-based ONSD/ETD ratio. The ONSD/ETD ratio ranged from 0.13 to 0.33, and a majority of individuals had a mean ratio of 0.22, and his ratio did not differ significantly between the right and left eyes

Table 3: Optic Nerve Sheath Diameter (ONSD) at 3mm, 6mm and 9mm and Optic Nerve Sheath Diameter/Eyeball Transverse Diameter (ONSD/ETD) Measurements

Mean measurement		Mean measurement	
R ONSD at 3 mm in cm	0.48±0.78	L ONSD at 3 mm in cm	0.49±0.94
R ONSD at 6 mm in cm	0.48±0.94	L ONSD at 6 mm in cm	0.49±0.96
R ONSD at 9 mm in cm	0.49±0.95	L ONSD at 9 mm in cm	0.49±0.97
Average R ONSD(of 3, 6, and 9 mm)	0.49±0.8	Average L ONSD (of 3, 6, and 9mm)	0.49±0.9
R ONSD/ETD at 3 mm	0.22±0.04	L ONSD/ETD at 3 mm	0.22±0.04
R ONSD/ETD at 6 mm	0.22±0.04	L ONSD/ETD at 6 mm	0.22 ±0.04
R ONSD/ETD at 9 mm	0.22±0.04	L ONSD/ETD at 9 mm	0.22±0.04
Average R ONSD/ ETD (of 3, 6, and 9 mm)	0.22	Average L ONSD/ ETD(of 3, 6, and 9 mm)	0.22

L: left; R; right

4. Discussion

It is a known fact that MRI provides better soft tissue resolution than CT and ONSD can be accurately measured using it. Detection of raised ICP in idiopathic intracranial hypertension and malfunctioning of shunts is easier in MRI than CT

Vaimanet al.[5] reported a strong correlation between ETD and ONSD for computed tomography measurements. This led toa proposal of using the ONSD/ETD ratio as a more-reliable parameter for increased ICP than ONSD alone.

Lagrèze WA et al., measured the optic nerve diameter at 0.5 mm, 10 mm and 15 mm behind the globe in a 3T MR system and observed better correlation between the optic nerve diameter and the Retinal Nerve Fiber Layer (RNFL), adjacent to the orbital apex than adjacent to the globe. Geeraerts T et al. studied ONSD in 36 healthy volunteers and 38 patients requiring ICP monitoring after severe traumatic brain injury. ICP was measured invasively during MRI scan, and ONSD was measured 3 mm posterior to the globe on axial T2-weighted fat-suppressed sequence on 3T MRI. They concluded that ONSD of less than 5.3 mm was not associated with raised ICP and that of more than 5.8 is associated with raised ICP.

In our study, there were no measurements with significant statistical differences between males and females, and no obvious correlation could be established between age and ON measurements. Majority of the cases showed a decrease in ONSD as the depth from the globe increased, but not necessarily in all cases. The ONSD/ETD ratio taken at various depths in both eyes showed a mean of 0.22mm, making it a better parameter.

5. Conclusion

In general, ONSD of the general population is independent of age, sex and has any mean of 4.7mm. Any subjects with values above this should be thoroughly investigated for intracranial hypertension. However, ONSD/ETD is a better parameter with its mean value of 0.22mm.

This study determined the normative range of MRI-based ONSD in healthy Indian adults. There was a strong association between the ETD and ONSD, which can be presented as the ONSD/ETD ratio. Our study suggests that the ONSD/ETD ratio is a more reliable indicator than ONSD itself; if this correlation is maintained in disease populations needs to be investigated further.

6. Abbreviations

Optic Nerve (ON), Optic Nerve Diameter (OND), Intracranial Pressure (ICP), Optic Nerve Sheath Diameter (ONSD), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Time to Repetition (TR), Time to Echo (TE), Field of view (FOV), Right (R), Left (L).

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