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Original article

ULTRASOUND MEASUREMENT OF OPTIC NERVE SHEATH DIAMETER IN A SAMPLE OF IRAQI ADULTS

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Abstract:

- ***Background***: Intracranial hypertension is a common life and vision threatening condition, intracranial pressure (ICP) can only be measured by invasive procedures. Distension of optic nerve sheath in association with raised ICP has been proven by the clinical trials. Transorbital sonographic measurement of optic nerve sheath diameter (ONSD) can be a simple noninvasive method for detection of raised ICP, however until now there is no consensus on upper normal limit of ONSD. The aim of the study is to measure optic nerve sheath diameter (ONSD) in healthy adults to provide normative data in a sample of Iraqi population.
- ***Method and patient:*** an observational cross-sectional study was conducted in Ibn Alhaitham eye teaching hospital, Baghdad, Iraq. Both eyes of 98 healthy adult volunteers aged 19 to 77 were examined using Absulu ultrasound machine with 20 MHz annular probe. Two measurements of ONSD were taken 3mm behind the eye globe and the average was calculated.
- ***Result:*** Optic nerve sheath diameter measurements ranged from 3.78mm to 7. 13mm.The mean was 5.54mm with standard deviation of 0.59mm and a median of 5.56mm. The 95% percentile was 6.53mm. There was no statistically significant relationship between ONSD measurement and gender or age.
- ***Conclusions:*** The mean ONSD measured by transorbital ultrasound was 5.54mm and the upper normal limit was 6.5mm (95% percentile) in a sample of Iraqi population.

- **Keywords:** Intracranial hypertension, intracranial pressure, optic nerve sheath, transorbital ultrasound.

INTRODUCTION

Intracranial hypertension is a common life and vision threatening syndrome caused by a variety of neurological and non-neurological diseases. Invasive intracranial devices that are either intra-parenchymal or intra-ventricular remain the gold standard for intracranial pressure (ICP) measurement. However, this technique is invasive and not always feasible due to a lack of facilities or contraindications such as coagulopathy. Moreover, ICP monitors can lead to complications such as hemorrhage, malfunction, or infection [(1)].

Neuroimaging by computed tomography (CT) scan and magnetic resonance imaging (MRI) can be used to predict intracranial hypertension, but these techniques are expensive, need long acquisition times, have limited availability, and impose harmful radiation exposure. Furthermore, CT scan has poor performance for detection of raised ICP [(2)].

Lumbar puncture opening pressure can also be used to diagnose elevated ICP. However, lumbar punctures carry risks as well, such as infection or bleeding, and can be time and resource intensive if performed on a critically ill patient [(3)].

Any pressure rises within the intracranial compartment impacts on the optic nerve head as swelling of the optic disc (papilledema). Ophthalmoscope examination for papilledema is one of the means for detecting raised ICP but the development of papilledema can take hours to many days [(4)], besides requiring a skilled observer for precise identification and differentiation from pseudo-papilledema which is not always possible.

Dilatation of the optic nerve sheath has been shown to be a much earlier manifestation of ICP rise [(5)]. Direct communication has been documented between the subarachnoid space of the optic nerve and the chiasmal cistern of the brain [(6)]. This communication allows the free transfer of CSF between the two compartments and possibly explains the intrathecal enhancement of the perioptic nerve space during myelography or cisternography [(7)]. The optic nerve sheath features a baseline diameter that remains constant as long as ICP is maintained within normcisternography. (ICP rises, CSF flows towards the perineural subarachnoid space and increases the pressure around the optic nerve. This results in expansion of the dural sheath and an increase in the ONSD [(8)]. Liu et al [(9)] confirmed the above phenomenon in fresh cadavers by performing saline infusions through a ventriculostomy to achieve various levels of ICP. They observed a linear relationship between the ICP, and the subarachnoid pressure of the optic nerve as recorded through an orbitotomy. Using optic nerve sonography or magnetic resonance imaging, several studies have demonstrated enlarged optic nerve sheaths in children and adults with raised ICP due to various pathologies and have established that increased ONSD is a sensitive sign of intracranial hypertension [(10)]. There is also evidence that enlargement of the optic nerve sheath is not a static indicator of intracranial hypertension but a dynamic phenomenon which varies with changes in the ICP [(8)].

Direct visualization of the optic nerve is possible by means of sonography. The method was pioneered in the 1970s by Ossoinig [(5)] who used A-scan technique to discern the optic nerve from the perineural sheath. In the next decades the B-scan technique was introduced, and the method was standardized and implemented mostly in ophthalmology for the assessment of ocular disorders. Modern high frequency transducers enable adequate penetration of the post bulbar area and quantification of the ONSD with a spatial resolution of 0.4 mm. Optic nerve sonography is relatively easy to perform and features a low inter- and intra-observer variability which is close to the intrinsic imaging ability of most modern ultrasound equipment [(11)]. Ultrasonographic measurement of the optic nerve sheath diameter (ONSD) a fixed distance from the retina provides a non-invasive, quick, inexpensive bedside method to predict and assist in the diagnosis of intracranial hypertension [(12)]. However, there has been no consensus on the optimal cut-off value of abnormal ONSD to indicate elevated ICP [(13)]. A wide variation is reported when ONSD was compared with invasive ICP monitoring, ranging from 4.8 to 5.9 mm [(14)].

The normal range of ONSD in healthy population is indispensable information to interpret the measurement of ONSD as a marker of intracranial hypertension. Moreover, it is still unknown whether there is a difference of ONSD values between Iraqi and other populations, as ONSD in Iraqi population has never been measured.

PATIENT and METHOD

A cross-sectional observational study, conducted at Ibn-AL Haitham eye teaching hospital, Baghdad, Iraq. Approval of the Iraqi board of medical specialties was obtained for the protocol of this study. A verbal consent was taken from all participants to be included in our study. Data collection started on October 2020 and ended in April 2021. No financial interests are involved in this study.

Exclusion criteria were history of any neurological disease, history of head trauma or surgery, patients taking medications that affect intracranial pressure, (mainly Vitamin A, tetracyclins, corticosteroids, oral contraceptives, cyclosporine, recombinant growth hormone and lithium), best corrected visual acuity less than 6/6 and signs of optic neuropathy on ophthalmological examination (afferent pupillary defect, optic disc swelling, pallor, and cupping).

Healthy Iraqi adults above the age of 18 years were evaluated by history taking to exclude any systemic or ocular condition that may affect intracranial pressure or the optic nerve. Ophthalmological examination included pupillary examination and visual acuity assessment by

Snellen's chart and fundus examination using slit lamp with a condensing lens (Volk 90D, Volk optical Inc. USA) to exclude signs of optic neuropathy (optic disc swelling, pallor and cupping).

Measurement of optic nerve sheath diameter was done by ultrasound B-mode examination. We used a high frequency 20 MHz ultrasound transducer annular probe from Absulu ultrasound machine, Quantel medical Inc. France done by single trained sonographer, all participants were examined in sitting position and asked to look straight forward, there is evidence that ONSD is not affected by patient position.[15] After application of coupling gel over closed eyelid, the probe is placed without pressure on the lateral half of upper eyelid with the transducer plane indicator in horizontal position, the probe is directed slightly caudally and nasally. We selected the orbit scan option provided in our ultrasound machine software. With the globe being in primary position a transverse (axial) section is taken through the globe and optic nerve complex.

The optic nerve appears as a hypoechoic band extending behind the globe surrounded by the hyperechoic orbital fat. The optic nerve sheath is identified as two dark more hypoechoic lines surrounding the optic nerve in the center. Optic nerve sheath diameter is measured 3mm behind the eye globe perpendicular to the axis of the optic nerve complex between the inner borders of the hypoechoic lines of optic nerve sheath. Two measurements were taken for each eye and the mean is calculated (figure 1). Despite the presence of an interocular symmetry between the ONSD of fellow eyes, dilatation of optic nerve sheath diameter can be asymmetrical, and cases of unilateral papilledema have been reported [16], therefore, in this study we took ONSD in each eye as a separate measurement, and in clinical practice the sonographic measurement of the ONSD should be performed bilaterally [8].

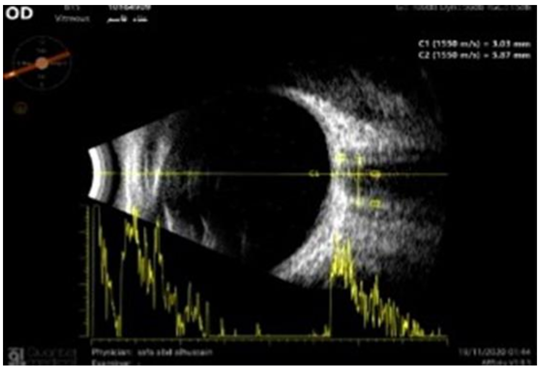

Figure 1: B- scan image showing horizontal (axial) section of optic nerve complex. hypoechoic lines of optic nerve sheath. caliber lines show our measurements taken 3mm behind the globe.

Statistical analysis of data was performed using IBM© SPSS (statistical package for social sciences software) version 26. Normality of data is tested by Shapiro-Wilk test. Mann-Whitney U test is used to compare optic nerve sheath diameter measurements between males and females. Wilcoxon matched pairs signed ranks test is used to compare measurements between right and left eyes. Kendall's-tau test is used to determine the correlation between ONSD and age. A two tailed P-value ≤ 0.05 is considered statistically significant.

RESULTS

Both eyes of 98 healthy adults are examined in Ibn-Al Haitham eye teaching hospital in an observational cross sectional study, a total of 196 eyes.

Demographic data

The age of studied sample individuals ranged between 19 and 77 years, with a mean age of 45.32 years, standard deviation 14.5 and a median of 47.5 years. Our study sample included both genders, 47 (48%) females and 51(52%) males. (Figure 2).

All volunteers were from Iraqi nationality.

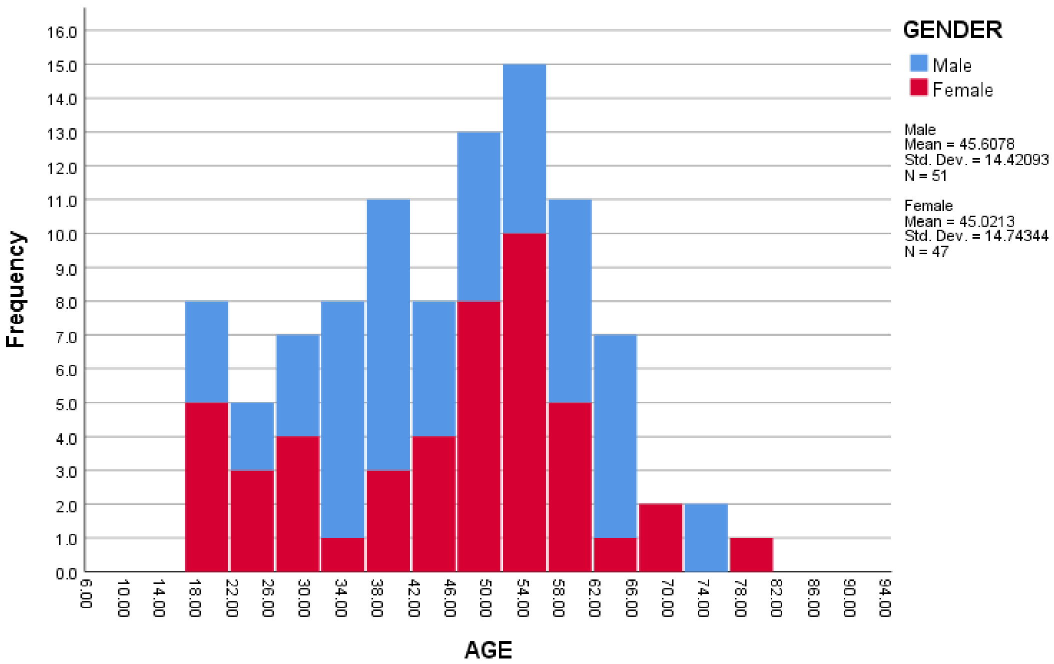

Figure 2: age and gender distribution of study sample

ONSD measurements

Intra-observer variability

Repeated measurements for the same eye by the same examiner are tested first for intra-observer variability. The intraclass correlation coefficient (ICC) was 0.82, which indicate good test repeatability. The standard error of measurement (SEM) was 0.25mm.

There was no significant statistic difference between repeated measurements of ONSD. Table 1 shows data and statistical analysis used to indicate the difference between repeated measurements.

Table 1: repeated measurements of ONSD

Side	ONSD mean ± SD		P–value*	ICC**	SEM
	1st reading	2nd reading			
Right	5.548 ± 0.62	5.542 ± 0.64	0.84	0.839	0.24 mm
Left	5.552 ± 0.62	5.524 ± 0.58	0.32	0.801	0.25 mm

*** Friedman's two way ANOVA test**
**** Intraclass Correlation Coefficient test**

Optic nerve sheath diameter

Optic nerve sheath diameter measurements in examined eyes (196) ranged from 3.78mm to 7. 13mm.The mean was 5.54mm with standard deviation of 0.59mm and a median of 5.56mm. The 95% confidence interval was 5.46-5.62mm. the 95% percentile was 6.53mm. Measured data of ONSD did not follow strict normal distribution (figure 3).

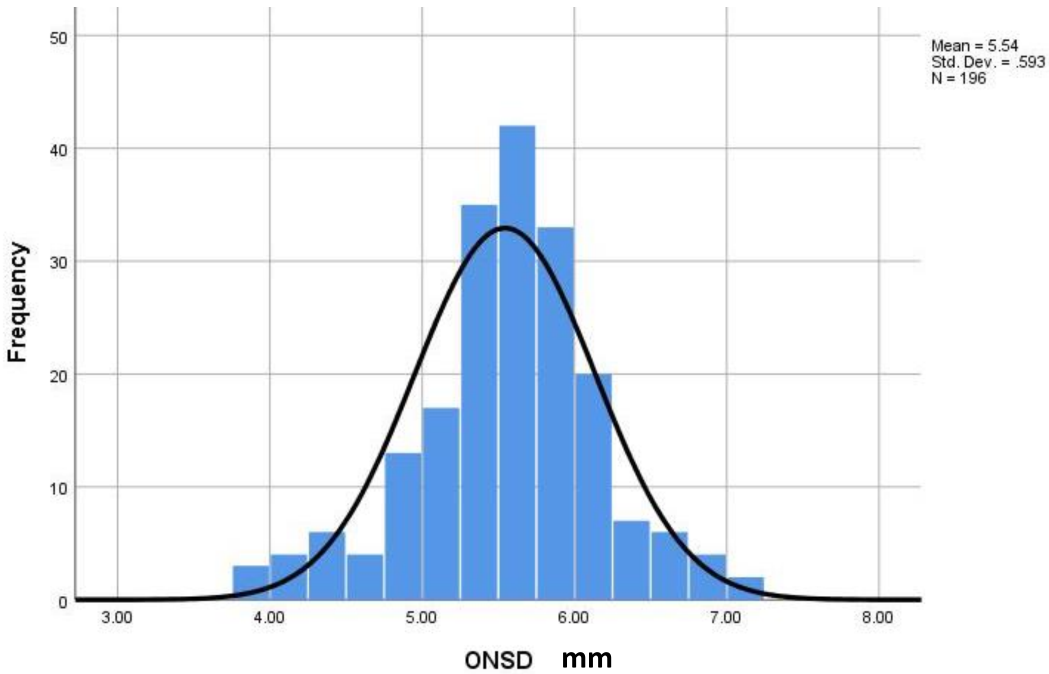

Figure 3: Mean values of ONSD histogram with normality curve

ONSD in right and left eyes

The median of ONSD in the right eye was 5.57mm. The mean was 5.54mm with standard deviation of 0.61mm. While in the left eye the median ONSD was 5.56mm, the mean was 5.53mm with a standard deviation of 0.57mm. There was no statistically significant difference in mean ONSD measurements between right and left eyes (table 2 and figure 4).

Table 2 ONSD in right and left eyes

ONSD mm	Right	Left
Mean	5.54	5.53
Median	5.57	5.56
Std. Deviation	0.61	0.57
Minimum	3.79	3.78
Maximum	7.13	7.01
P value*	0.915	
*Wilcoxon Signed Ranks Test		

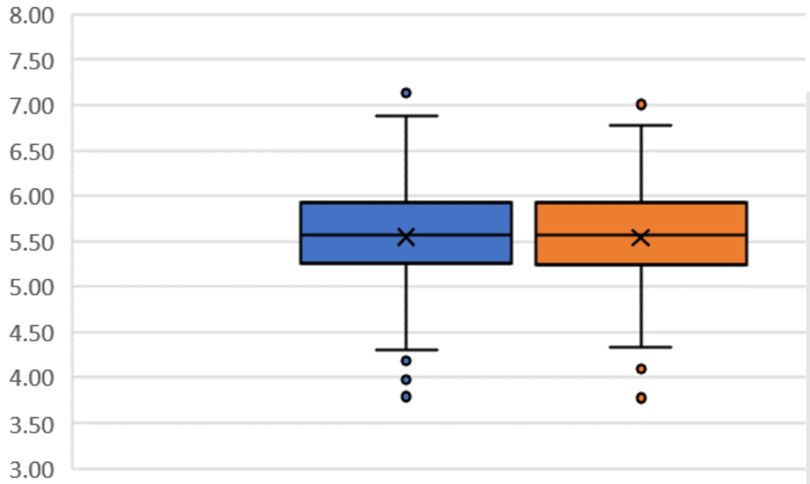

Figure 4: Mean ONSD in right and left eyes. Box and whiskers chart showing the mean (×), median (center line), quartiles (box), minimum and maximum measurements (fences and outliers)

ONSD measurements in different genders

The mean optic nerve sheath diameter measurement in males was slightly higher than females with a mean ONSD of 5.63mm, standard deviation 0.47mm, median 5.59mm and a 95% percentile of 6.60mm. While in females the mean ONSD was 5.44mm, the standard deviation 0.69mm, the median 5.50mm and the 95% percentile was 6.52mm. This difference between genders in our study was not statistically significant as the p-value is higher than 0.05 as illustrated in table 3 and figure 5.

Table 3 ONSD measurements in different genders

ONSD mm	Male	Female
Mean	5.63	5.44
Median	5.59	5.50
Std. Deviation	0.47	0.69
Minimum	4.35	3.78
Maximum	6.80	7.13
95% percentile	6.60	6.52
Number	51	47
P value*	0.076	
* Mann-Whitney U test		

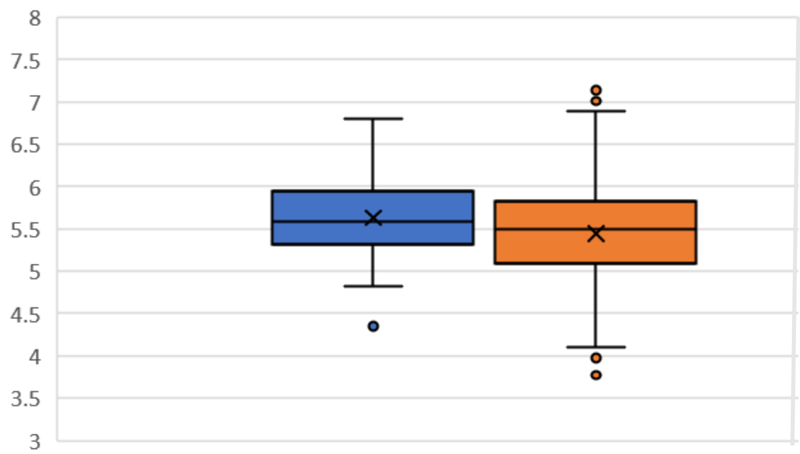

Figure 5: ONSD measurement in different genders. Box and whiskers chart showing the mean (×), median (center line), quartiles (box), minimum and maximum measurements (fences and outliers)

ONSD measurement difference with age

In our study, volunteers aged between 19 and 77 years were examined for ONSD. There was a mild positive correlation between ONSD and age with a Kendall-tau correlation coefficient of 0.048, but this was not statistically significant as the p-value was 0.32 (higher than 0.05).

ONSD measurements in different age groups (divided into decades) are illustrated in figure 6 and table 4. Figure 6 shows ONSD distribution with age. There was no statistically significant difference in ONSD between age groups.

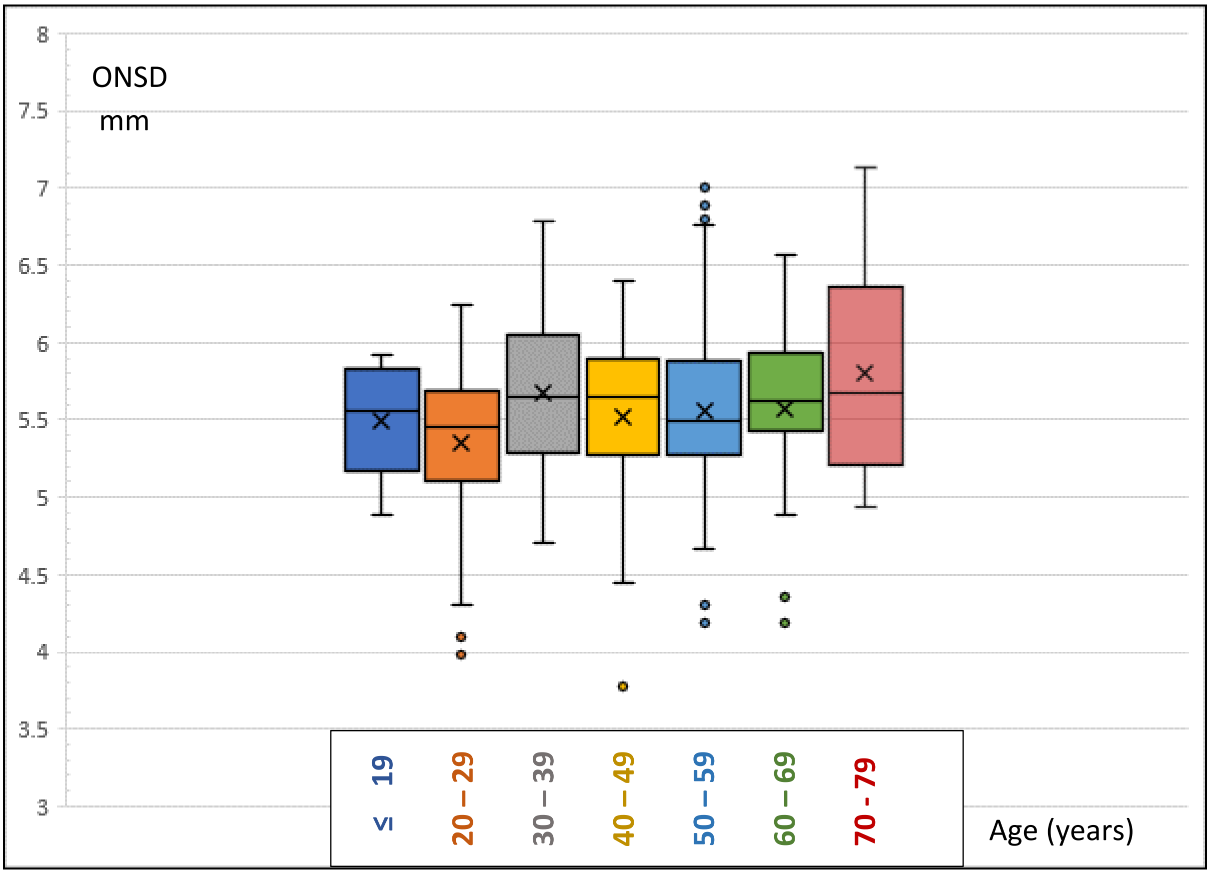

Figure 6: ONSD measurements in different age groups. Box and whiskers chart showing the mean (×), median (center line), quartiles (box), minimum and maximum measurements (fences and outliers).

Table 4: ONSD measurement in different age groups

ONSD (mm)	Age (years) ≤ 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79
Mean	5.49	5.35	5.67	5.52	5.55	5.57	5.80
Median	5.56	5.45	5.64	5.65	5.49	5.62	5.67
Std. Deviation	0.38	0.57	0.52	0.58	0.65	0.57	0.78
95 % percentile *	-	6.21	6.59	6.36	6.79	6.47	-
Minimum	4.88	3.98	4.7	3.78	4.19	4.19	4.94
Maximum	5.92	6.24	6.78	6.40	7.01	6.56	7.13
Number	3	15	16	18	30	13	3
P – value **	0.495						

* 95% percentile not calculated in 1st and last group because of small sample number.
** Kruskal Wallis Test

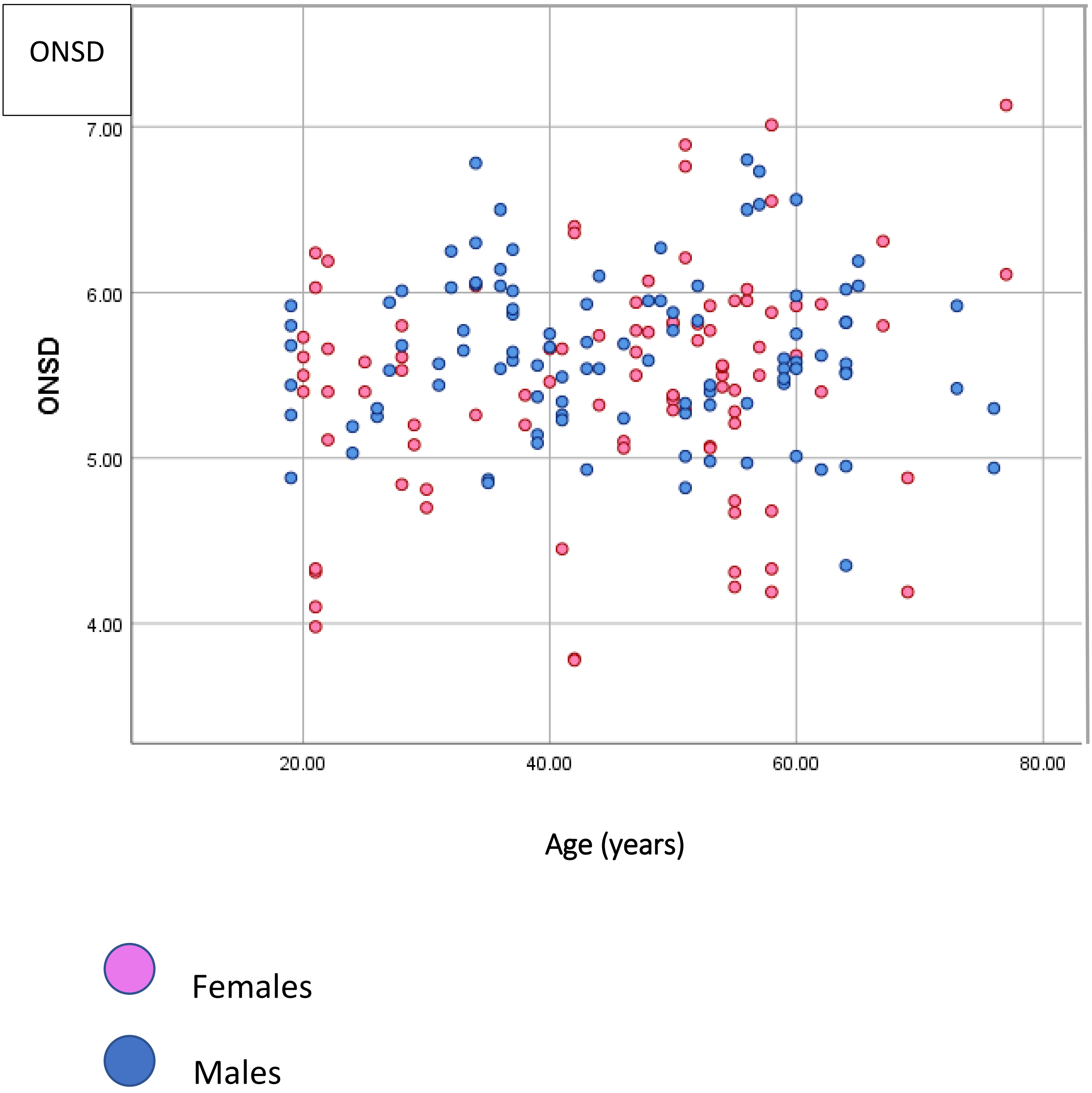

Figure 7: scatter dot chart of ONSD with age and marking for genders.

DISCUSSION

Measurement of optic nerve sheath diameter is potentially a noninvasive simple method to detect raised intracranial pressure as the distention of optic nerve sheath in association with raised ICP have been proved in cadaveric and clinical trials [8,9].

In our study, the mean of normal optic nerve sheath diameter was 5.54mm with upper normal limit of 6.53mm (95% percentile). Similar results are seen in Bauerle et al [17-19] in Germany with a mean ONSD of 5.4mm. Kishk NA et al [20] in Egypt reported a mean ONSD of 5.55mm. Several studies showed a larger optic nerve sheath diameter mean and upper normal limit. In De Masi et al [21] the mean optic nerve sheath diameter was 6.5mm. Lochner P et al [22] showed a mean ONSD of 5.95mm. These two studies reported the highest ONSD, and both are done in Italy. Many other studies showed smaller ONSD. Kim DH et al [23] in Korea showed a mean ONSD of 4.11mm. The lowest mean ONSD measured is by legorova KS et al [24] in Ukraine that reported a mean ONSD of 4.08mm. Difference in examination technique is one reason for this variability in ONSD among studies. Different type of machines and different transducer frequency used in the studies affect obtained image resolution and ONSD measurements. Racial and ethnical differences are factors to be considered in ONSD variation among studies. The optic nerve sheath being a mobile, fluid filled structure is a possible source of this variation.

In this study we did not find a significant correlation between ONSD and age, this is consistent with the studies that measured ONSD in adults. Steinborn et al [25] measured ONSD in children aged 3 months to 17 years using transorbital ultrasound and MRI found a positive correlation between ONSD and age up to 5 years old after which there was no significant increase in ONSD.

Limitations to point in our study is that all examined volunteers are considered to be healthy with normal ICP, since measurement of ICP requires invasive procedures.

Financial support and sponsorship:

Nil.

Conflicts of interest:

There are no conflicts of interest.

CONCLUSION

The mean ONSD measured by transorbital ultrasound was 5.54mm and the upper normal limit was 6.5mm (95% percentile) in a sample of healthy Iraqi population. There is no correlation between ONSD measurements with age or gender.

REFERENCES

1. Raboel PH, Bartek J, Andresen M, Bellander BM, Romner B. Intracranial pressure monitoring: Invasive versus non-invasive methods-A review. Critical Care Research and Practice. 2012; 12(8) : 114-17.
2. Hiler M, Czosnyka M, Hutchinson P, Balestreri M, Smielewski P, Matta B, et al. Predictive value of initial computerized tomography scan, intracranial pressure, and state of autoregulation in patients with traumatic brain injury. J Neurosurg. 2006;104(5):731–7.
3. Hylkema C. Optic Nerve Sheath Diameter Ultrasound and the Diagnosis of Increased Intracranial Pressure. Critical Care Nursing Clinics of North America. W.B. Saunders. 2016; 28(1): 95–9.
4. Raghunandan N, Joseph M, Nithyanandam S, Karat S. Role of ultrasonographic optic nerve sheath diameter in the diagnosis and follow-up of papilledema and its correlation with Frisén's severity grading. Indian J Ophthalmol. 2019 ;67(8):1310–3.
5. Ossoinig KC. Standardized echography: Basic principles, clinical applications, and results. International Ophthalmology Clinics. 1979; 19(4) : 127–210.
6. Killer HE, Laeng HR, Flammer J, Groscurth P. Architecture of arachnoid trabeculae, pillars, and septa in the subarachnoid space of the human optic nerve: Anatomy and clinical considerations. Br J Ophthalmol. 2003;87(6):777–81.
7. MI R, GH Z. The orbit. In: Sutton D, editor. Textbook of radiology and imaging. 7th ed. London: Churchill Livingstone; 2003 : 1573–90.
8. Soldatos T, Chatzimichail K, Papathanasiou M, Gouliamos A. Optic nerve sonography: A new window for the non-invasive evaluation of intracranial pressure in brain injury. Emergency Medicine Journal. 2009; 26(9) : 630–4.
9. Liu D, Kahn M. Measurement and relationship of subarachnoid pressure of the optic nerve to intracranial pressures in fresh cadavers. Am J Ophthalmol. 1993;116(5):548–56.
10. Tayal VS, Neulander M, Norton HJ, Foster T, Saunders T, Blaivas M. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. Ann Emerg Med. 2007;49(4):508–14.
11. Ballantyne SA, O'Neill G, Hamilton R, Hollman AS. Observer variation in the sonographic measurement of optic nerve sheath diameter in normal adults. Eur J Ultrasound. 2002;15(3):145–9.
12. Chacko J. Optic nerve sheath diameter: An ultrasonographic window to view raised intracranial pressure. Indian Journal of Critical Care Medicine. Medknow Publications. 2014; 18(11) : 707–8.
13. Moretti R, Pizzi B. Ultrasonography of the optic nerve in neurocritically ill patients. . Acta Anaesthesiologica Scandinavica. 2011; 37(7): 644–52.
14. Rajajee V, Vanaman M, Fletcher JJ, Jacobs TL. Optic nerve ultrasound for the detection of raised intracranial pressure. Neurocrit Care. 2011;15(3):506–15.

15. Romagnuolo L, Tayal V, Tomaszewski C, Saunders T, Norton HJ. Optic nerve sheath diameter does not change with patient position. Am J Emerg Med 2005;23(5):686–8
16. Killer HE, Jaggi GP, Flammer J, et al. The optic nerve: a new window into cerebrospinal fluid composition. Brain 2006;129:1027–30.
17. Bäuerle J, Nedelmann M. Sonographic assessment of the optic nerve sheath in idiopathic intracranial hypertension. J Neurol. 2011;258(11):2014–9.
18. Bäuerle J, Lochner P, Kaps M, Nedelmann M. Intra- and interobsever reliability of sonographic assessment of the optic nerve sheath diameter in healthy adults. J Neuroimaging. 2012;22(1):42–5.
19. Bäuerle J, Schuchardt F, Schroeder L, Egger K, Weigel M, Harloff A. Reproducibility and accuracy of optic nerve sheath diameter assessment using ultrasound compared to magnetic resonance imaging. BMC Neurol. 2013;13(9):187.
20. Kishk NA, Ebraheim AM, Ashour AS, Badr NM, Eshra MA. Optic nerve sonographic examination to predict raised intracranial pressure in idiopathic intracranial hypertension: The cut-off points. Neuroradiol J. 2018;31(5):490–5.
21. De Masi R, Orlando S, Conte A, Pasca S, Scarpello R, Spagnolo P, et al. Transbulbar B-Mode Sonography in Multiple Sclerosis: Clinical and Biological Relevance. Ultrasound Med Biol. 2016;42(12):3037–42.
22. Lochner P, Coppo L, Cantello R, Nardone R, Naldi A, Leone MA, et al. Intra- and interobserver reliability of transorbital sonographic assessment of the optic nerve sheath diameter and optic nerve diameter in healthy adults. J Ultrasound. 2014;19(1):41–5.
23. Kim DH, Jun J-S, Kim R. Ultrasonographic measurement of the optic nerve sheath diameter and its association with eyeball transverse diameter in 585 healthy volunteers. Sci Rep. 2017;7(1):15906.
24. Iegorova KS, Zadoianyi LV ML. Optic nerve ultrasound in idiopathic intracranial hypertension. Oftalmol Zh. 2016; 4: 29–32.
25. Steinborn M, Fiegler J, Ruedisser K, Hapfelmeier A, Denne C, Macdonald E, et al. Measurement of the Optic Nerve Sheath Diameter in Children: Comparison Between Transbulbar Sonography and Magnetic Resonance Imaging. Ultraschall Med. 2012;33(6):569–73.