P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : https://tci-thaijo.org/index.php/SciTechAsia
Science & Technology Asia
Vol.26 No.3 July - September 2021
Page: [167-173]
Original research article

Measurement of Normal Diameter of Optic Nerve and Optic Nerve Sheath Using MRI

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Received 17 October 2019; Received in revised form 20 May 2020
Accepted 16 July 2020; Available online 6 September 2021

ABSTRACT

We aim to establish normal diameters of optic nerve and optic nerve sheath on magnetic resonance imaging. Measurement of optic nerve and optic nerve sheath was done on the 102 volunteers who came for cranial magnetic resonance imaging examination at Thammasat University Hospital. The volunteers were free of orbital disorders or known related diseases that might affect optic nerve or optic nerve sheath and no contraindications in performing in the magnetic resonance imaging study. Diameters of optic nerve and optic nerve sheath at 3 mm and 8 mm in distance behind the eye globe were measured in parallel plane to optic nerve on axial T2-weighted turbo spin echo fat-suppressed sequence. Normal diameters of right/left optic nerve at 3 mm and 8 mm behind the eye globe (mean ± 2standarad deviations) are 2.76 ± 0.66 mm/2.74 ± 0.66 mm and 2.32 ± 0.60 mm/2.31 ± 0.53 mm, respectively. The normal right/left optic nerve sheath diameters at 3 mm and 8 mm behind the eye globe (mean ± 2standarad deviations) are 5.10 ± 1.07 mm/5.13 ± 1.03 mm and 4.38 ± 0.91 mm/ 4.36 ± 0.75 mm, respectively. No correlation present between age and size of optic nerve and optic nerve sheath as well as no difference of optic nerve and optic nerve sheath diameters between both eyes are found. For comparison of optic nerve and optic nerve sheath between males and females, most values show no statistically significant difference except for in the bilateral optic nerve sheath diameters and right optic nerve diameter at 3 mm behind eye globe. Normal diameters of optic nerve and optic nerve sheath at 3 mm and 8 mm from the eye globe were established. This information could be helpful in diagnosis some diseases or in excluding some conditions.

Keywords: MRI; Normal diameter of optic nerve; Normal diameter of optic nerve sheath; Optic nerve; Optic nerve sheath; Size of optic nerve; Size of optic nerve sheath

1. Introduction

As various common pathologies affect diameters of the optic nerve (ON) and optic nerve sheath (ONS) such as thyroid-associated orbitopathy, optic neuritis, optic nerve atrophy, optic nerve glioma, optic

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nervesheath meningioma, orbital pseudotumor, pseudotumor cerebri and other kinds of increased intracranial pressure, etc. it is therefore important to know what constitutes normal concerning ON and ONS diameters, for the diagnosis and differentiation of these diseases.

Though there is previous research on the normal size of the optic nerve sheath complex using computed tomography (CT) in the Thai population [1], to the best of our knowledge, there is still no research establishing the normal diameter of the ON and ONS using magnetic resonance imaging (MRI) in the Thai population. Furthermore, MRI plays an important role in the evaluation of ON and ONS as it has many advantages over CT such as the absence of ionizing radiation, better soft tissue contrast, etc.

Using CT can measure only the optic nerve sheath complex (optic nerve and its sheath altogether). Due to the better soft tissue contrast of MRI, it can differentiate ON from ONS and measure them separately. This could be useful because different diseases affect different parts of the optic nerve sheath complex; some affect the optic nerve and some affect the optic nerve sheath.

The purpose of this study was to measure diameters of ON and ONS and determine the normal values. Correlation of these normal diameters between both eyes and age as well as comparison of these diameters and gender were also evaluated. It is expected that the result of this study could aid in the diagnosis of some diseases or the exclusion of some conditions.

2. Materials and Methods

2.1 Subjects

This prospective study was approved by the Research Ethics Board of the Faculty of Medicine, Thammasat University.

All MR images in this study were obtained from adult patients (age more than 18 years old) who came for cranial MRI at Thammasat Hospital, Pathum Thani, Thailand from October 2017 to November 2018.

According to medical documents and personal interviews, the patients were free of orbital disorders or known related diseases that might affect the optic nerve or optic nerve sheath such as endocrinopathy, any kinds of increased intracranial pressure, etc. Moreover, the patients had no contraindications in performing the MRI study.

2.2 Sample size

This study used the values of mean and standard deviation (SD) of ONS from the prior CT study in the Thai population [1] which were 5.6 mm and 0.9 mm, respectively. This study also used the values of mean and SD of ON from a study by Geeraerts T et al [2] which were 2.7 mm and 0.23 mm, respectively. The calculated power and effected size are 0.80 and 0.25 mm, respectively. From the mentioned information, the number of subjects was calculated using estimated sample size for one- sample comparison of mean from STATA software version 12.1. The result for estimated required patients was 102.

2.3 Methods

Raw data of MRI were collected using Siemens SKYRA 3 Tesla MRI. The axial T2-weighted turbo spin echo fat-suppressed sequence was used to measure ONS and ON diameters. The scan parameters were as follows: echo time 67 ms, repetition time 5820 ms, slice thickness 2 mm, pixel bandwidth 150 Hz/pixel, FOV read 160 mm, and number of slices 23.

The patients were asked to maintain forward gaze and gentle eye closure during the scans. Axial scans were obtained parallel to the optic nerve. On MRI, the optic nerve sheath appeared as a high signal intensity surrounding the optic nerve. The optic nerve appeared as a structure of low signal intensity. The optic nerve sheath and optic nerve diameters from both sides were measured perpendicular to their courses on axial section at 3 mm and 8 mm behind the

eye globe [3-4] using an electronic caliber in picture archiving and communication system (PACS) (Figs. 1-3).

The measurement was performed by one neuroradiologist (10 years experience) choosing an image slice in which the entire intraorbital course of ON/ONS was visualized.

Mean diameter of ONS had maximal variation at 3 mm behind the eye globe, sensible for monitoring some conditions such as increased ICP [3]. In contrast, the mean diameter of ONS had minimal variation at 8 mm behind the eye globe, proper for referencing normal value [3]. Therefore, measurement was done at these points.

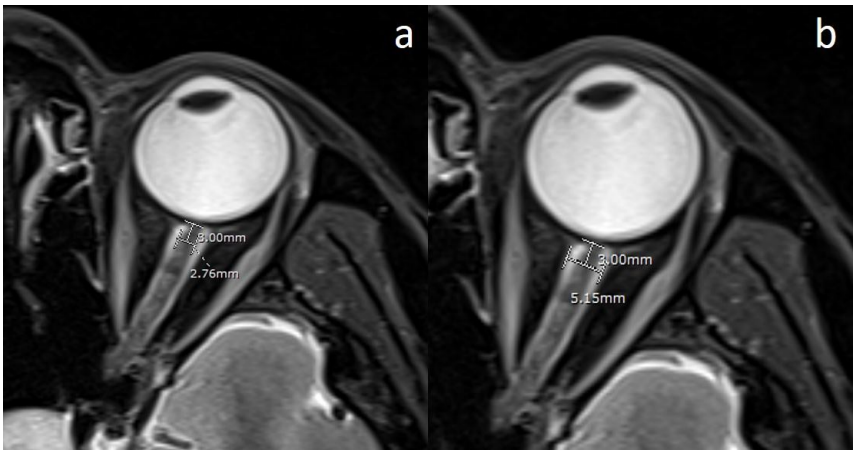

Fig. 1. Measurement of diameters of optic nerve (a) and optic nerve sheath (b) at 3 mm behind the eye globe.

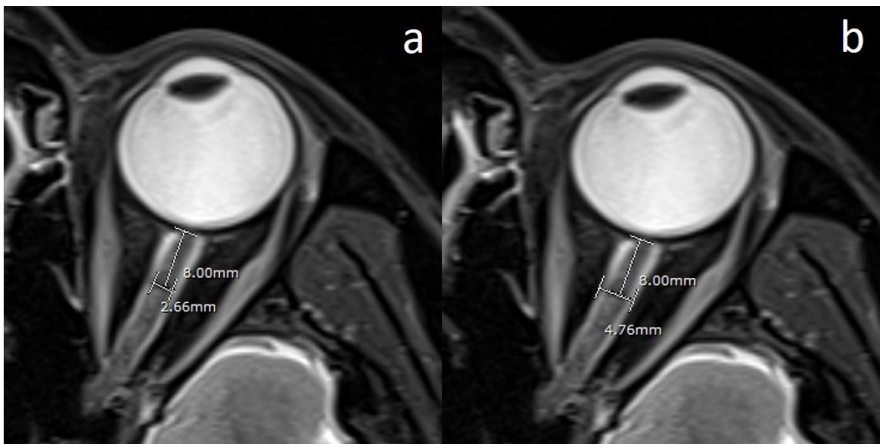

Fig. 2. Measurement of diameters of optic nerve (a) and optic nerve sheath (b) at 8 mm behind the eye globe.

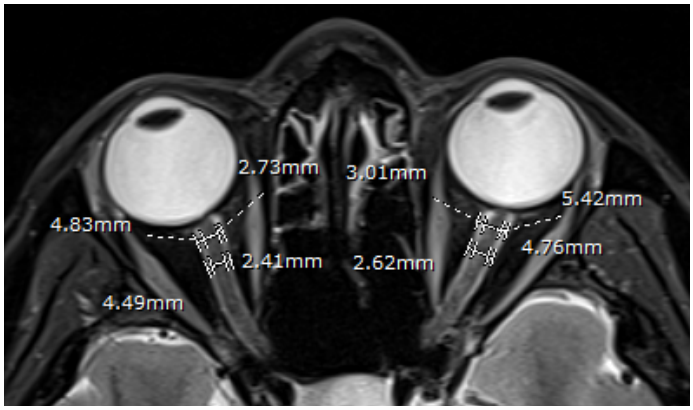

Fig. 3. Measurement of bilateral optic nerve and optic nerve sheath diameters at 3 mm and 8 mm behind the eye globe.

2.4 Statistical analysis

All statistical analyses in our study were done using IBM SPSS statistics 23 for windows.

The normal diameters of optic nerve and optic nerve sheath at 3 mm and 8 mm behind the eye globe are expressed as mean ± 2SDs.

Comparison of optic nerve and optic nerve sheath diameters between both eyes were calculated using Pair t-test.

Correlation between age and diameter of optic nerve and optic nerve sheath were calculated using Pearson' s correlation.

Comparison of diameter of optic nerve and optic nerve sheath between males and females were calculated using independent-sample t-test.

2.5 Results

In our prospective study, there were 42 males and 60 females. Ages ranged from 19 to 89 years, with the distribution shown in figure 4. Altogether, 204 optic nerves and optic nerve sheaths were measured.

Normal diameter (mean ± 2SDs) and range of ON and ONS at 3 mm and 8 mm behind the eye globe are shown in Table 1.

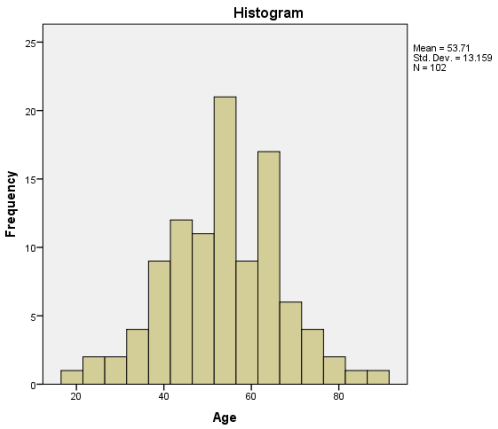

Fig. 4. Histogram shows age distribution of 102 patients.

No statistically significant difference of ON and ONS diameters between both eyes is noted (Table 2). There was also no correlation between age and diameter of ON and ONS (Table 3). For comparison of ON and ONS between genders, most *p*-values show no statistically significant difference except bilateral ONS diameters and right ON diameter at 3 mm behind the eye globe (Table 4).

In these following tables, OND stands for optic nerve diameter while ONSD stands for optic nerve sheath diameter.

Table 1. Normal diameter of bilateral optic nerves and optic nerve sheathes at 3 mm and 8 mm behind the eye globe (mm).

	Mean ± 2SDs	Range
Right OND at 3 mm	2.76 ± 0.66	2.04 – 3.72
Right OND at 8 mm	2.32 ± 0.60	1.68 – 3.15
Right ONSD at 3 mm	5.10 ± 1.07	4.00 – 6.50
Right ONSD at 8 mm	4.38 ± 0.91	3.15 – 5.49
Left OND at 3 mm	2.74 ± 0.66	1.92 – 3.53
Left OND at 8 mm	2.31 ± 0.53	1.75 – 3.08
Left ONSD at 3 mm	5.13 ± 1.03	3.97 – 6.40
Left ONSD at 8 mm	4.36 ± 0.75	3.70 – 5.46

Table 2. Comparison of optic nerve and optic nerve sheath between both eyes at 3 mm and 8 mm behind the eye globe with paired samples t-test. Statistically significant at p-value < 0.05.

Type and location	t	p-value
ONSD at 3 mm	-0.908	0.366
ONSD at 8 mm	0.933	0.353
OND at 3 mm	1.000	0.320
OND at 8 mm	0.526	0.600

Table 3. Pearson Correlation between age and size of optic nerve diameter (OND) and optic nerve sheath diameter (ONSD) at 3 mm and 8 mm behind eye globes (N = 102). Statistically significant at p-value < 0.05.

Size	Pearson correlation (r) N=102	
	Right	**Left**
ONSD at 3 mm	-0.20 (p-value = 0.041)	-0.22 (p-value = 0.030)
ONSD at 8 mm	-0.11 (p-value = 0.279)	-0.09 (p-value = 0.360)
OND at 3 mm	-0.12 (p-value = 0.246)	-0.12 (p-value = 0.240)
OND at 8 mm	-0.02 (p-value = 0.832)	-0.05 (p-value = 0.615)

Note: Low correlation $-0.50 \le r \le 0.50$, Moderate correlation $0.50 < r < 0.80$ or $-0.80 < r < -0.50$, High correlation $r \ge 0.80$ or $r \le -0.80$.

Table 4. Comparison of optic nerve and optic nerve sheath diameters between male and female with independent samples t-test (Male=42, Female=60). Statistically significant at p-value < 0.05.

Type and location	Sex (n)	Mean (SD)	t	p-value
Rt. ONSD at 3 mm	Male (42) Female (60)	5.25 (0.58) 4.99 (0.47)	2.427	0.018*
Lt. ONSD at 3 mm	Male (42) Female (60)	5.32 (0.53) 5.00 (0.47)	3.122	0.002*
Rt. ONSD at 8 mm	Male (42) Female (60)	4.49 (0.52) 4.31 (0.39)	1.933	0.057
Lt. ONSD at 8 mm	Male (42) Female (60)	4.43 (0.38) 4.31 (0.37)	1.594	0.115
Rt. OND at 3 mm	Male (42) Female (60)	2.86 (0.35) 2.70 (0.31)	2.382	0.020*
Lt. OND at 3 mm	Male (42) Female (60)	2.78 (0.31) 2.71 (0.35)	1.009	0.316
Rt. OND at 8 mm	Male (42) Female (60)	2.39 (0.33) 2.27 (0.27)	1.880	0.064
Lt. OND at 8 mm	Male (42) Female (60)	2.33 (0.24) 2.30 (0.28)	0.606	0.546

3. Discussion

MRI is a widely used technique for imaging the orbit because of its high spatial resolution, lack of ionizing radiation, and multiplanar imaging capacity, making MRI superior to CT in ON and ONS imaging.

The ON and ONS were well visualized in the current MRI examination. Knowing normal sizes of ON and ONS could be helpful in the diagnosis or exclusion of some diseases.

The study by Vaiman M et al. [3] found that mean diameter of ONS had maximal and minimal variation at 3 mm and 8 mm behind the eye globe, respectively. In our view, this has both advantages and disadvantages. For example, ONS diameter at 3 mm behind the eye globe, the point of highest variation, is sensible for monitoring some conditions such as increased intracranial pressure, in spite of its comparatively low specificity.

Meanwhile ONS diameter at 8 mm behind the eye globe, the most stable size, is proper for referencing a normal value. This might be useful for radiological, neurological, and ophthalmological practice. Therefore, we chose to measure ON and ONS at 3 mm and 8 mm behind the eye globe in our study.

In our prospective study, in order to ensure the accuracy of measurement of the diameter of ON and ONS, some protocols were used as follows:

- The patients were asked to maintain looking forward and gently close their eyes during the examination so that raw image data of ON and ONS were confidently acquired in neutral eye position.
- Axial scans were obtained in parallel plane to ON.
- Using thin slice (2- mm thickness) allowed high spatial resolution.
- Fat suppression T2W sequence to suppress orbital fat surrounding ONS improved soft tissue contrast between perioptic CSF and intraconal orbital fat.

Normal diameters of ONS at 3 mm & 8 mm and of ON at 3 mm behind the eye globes obtained from our study corresponded with findings of prior studies [1- 3, 5- 6] whereas there is no previous study of normal diameter of ON at 8 mm behind the eye globe, to the best of our knowledge.

The authors' results show no correlation between age and size of ON and ONS as well as no difference of ON & ONS diameters between both eyes. These correlations correspond with prior studies [1, 3, 5- 6].

Comparison of the diameters of ON and ONS between males and females revealed no statistically significant difference for most values, concordant with the findings of previous studies [1, 3, 5-6] . However, there were few values-bilateral ONS diameters and right ON diameter at 3 mm behind the eye globe-which showed significantly larger measurements in males than in female (Table 5). These differences are probably due to unequal numbers of males and females in our study, as well as the high variation in the size of ONS at 3 mm behind the eye globe. Another possible explanation is that there is a true difference in these values between genders.

Table 5. Normal diameter of right optic nerve and bilateral optic nerve sheathes at 3 mm behind the eye globe (mm) in males and females.

	Right OND at 3 mm Mean ± 2SDs	Right ONSD at 3 mm Mean ± 2SDs	Left ONSD at 3 mm Mean ± 2SDs
Male	2.86 ± 0.69	5.25 ± 1.16	5.32 ± 1.05
Female	2.70 ± 0.61	4.99 ± 0.95	5.00 ± 0.94

As different diseases involve different parts of the optic nerve sheath complex, some affect ON (ex. optic nerve glioma) whereas some affect ONS (ex. optic nerve sheath meningioma). Knowledge of the normal diameter of ON and ONS helps to raise the precision with which some pathologies are diagnosed or ruled out as possibilities.

4. Limitations

The study is limited by the non-uniform age and gender distribution of the participants. The rather middle age group and predominance of females in the study may affect the correlation of age and diameters of ON and ONS as well as the comparisons between males and females. Another limitation is that the data was collected from a single center which may not fully represent the entire Thai population. Multicenter trials could provide more accurate results.

5. Conclusion

In conclusion, this study presents and guides the values of normal diameters of ON and ONS at 3 mm and 8 mm behind the

eye globe taken by MRI. We hope that our results may help observers to accurately assess enlargement or atrophy of ON and ONS. These could help in the diagnosis and differential diagnosis of some diseases or help in the excluding of some conditions.

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