

# Normal Measurements of Optic Nerve in Pediatric Population

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## ABSTRACT

**Objective:** The aim of this study was to examine the normal values of the optic nerve in different segments of the nerve trace in the pediatric population using magnetic resonance imaging (MRI).

**Methods:** Two radiologists retrospectively reviewed images obtained with a 1.5 tesla MR device of 426 youngsters (213 males/213 girls). Measurements were performed on the T2 sequence. Parts of the orbital region, prechiasmatic region, and optic tract were measured. Participants were divided into 5 different age groups.

**Results:** The mean age of the population is  $8.3 \pm 1.5$  years. The average diameter of the orbital segment of the entire population was  $3.58 \pm 0.53$  mm,  $4.74 \pm 0.48$  mm for the prechiasmatic segment, and  $3.61 \pm 0.48$  mm for the optic tract section. Age correlates positively with the orbital plane (OP), prechiasmatic portion (PP), and optic tract (OT) values. All age groups have considerably varying mean OP, PP, and OP diameters. Good interobserver reliability was observed for all 3 diameter measurements (OP cap value = 0.62, PP cap value = 0.58, OT cap value = 0.67).

**Conclusion:** Normal diameters of the optic nerve can be measured by MRI at above mentioned sections with a good interobserver reliability. These normal values can be used to detect obscure thickness changes/abnormalities in optic nerves of the children.

**Keywords:** Optic nerve, pediatric, measurement, MRI

## INTRODUCTION

The optic nerve is an important component of the visual system that transmits visual data from the eye to the brain. It consists of around 1200000 axons that arise from retinal ganglion cells in the eye and converge to produce the optic nerve head or optic disc.<sup>1</sup> The optic nerve begins at the optic disc, located on the retina, and travels through the optic canal in the sphenoid bone, eventually reaching the optic chiasm, where the nerve fibers from both eyes partially cross.<sup>2</sup> The axons from the nasal (medial) half of each retina cross to the opposite side, whereas those from the temporal (lateral) half remain on the same side. After the optic chiasm, the fibers continue as the optic tracts, which eventually synapse at the lateral geniculate nucleus of the thalamus.<sup>3</sup> The blood supply to the optic nerve is primarily from the ophthalmic artery and its branches, including the central retinal artery and the posterior ciliary arteries.<sup>4</sup> The optic nerve's primary

function is to transmit visual information from the retina to the brain for processing. It conveys information about brightness, color, and contrast, as well as the spatial and temporal properties of the visual scene.<sup>5</sup> Diseases such as glaucoma, optic neuritis, and ischemic optic neuropathy can cause damage to the optic nerve.<sup>6</sup>

Evaluation of optic nerve parameters is critical for diagnosing a variety of ophthalmic and neurologic disorders in children. Common methods for assessing the optic nerve in pediatric patients are outlined below. Ophthalmoscopy is a non-invasive method for observing the optic nerve head directly. This can be done using a handheld ophthalmoscope or a slit-lamp biomicroscope. It is possible to evaluate the size, shape, and color of the optic disc, as well as the existence of any abnormalities, such as optic disc edema or optic atrophy. This technique is frequently employed in clinical practice and has been validated by multiple studies.<sup>7</sup> Optical

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coherence tomography (OCT) is a non-invasive imaging technology that utilizes light waves to generate high-resolution cross-sectional pictures of the optic nerve head and surrounding tissues. It permits the objective measurement of factors including optic nerve head diameter, cup-to-disc ratio, and retinal nerve fiber layer thickness. In pediatric populations, OCT has demonstrated reliability and reproducibility.<sup>8</sup> Ultrasound is an imaging method that uses high-frequency sound waves to create images of the optic nerve and its surrounding components. It can be used to measure the optic nerve head's diameter and length axially. In pediatric populations, ultrasound has been used to diagnose disorders such as optic nerve hypoplasia.<sup>9</sup> Magnetic resonance imaging (MRI) is a non-invasive imaging technique that uses a magnetic field and radio waves to produce detailed images of the brain and optic nerves. It can be used to visualize the optic nerves and surrounding structures and detect abnormalities such as optic nerve gliomas. Magnetic resonance imaging is often used in pediatric populations for the evaluation of neurologic and ophthalmic conditions.<sup>10</sup>

Many medical disorders can damage the optic nerve, including optic neuritis, optic nerve hypoplasia, papilledema, optic neuropathy, optic nerve tumors, and congenital defects. Early diagnosis and treatment are essential for preserving vision and preventing further damage to the optic nerve; therefore, normative values for optic nerve measurements on MRI in the pediatric population are required for correctly interpreting results and diagnosing ocular and neurological disorders. Many studies addressing the normative values for optic nerve measurements in MRI in pediatric populations have been undertaken, with various techniques and results. This study aims to determine the normal values of the optic nerve in different segments of the nerve trace in normal pediatric cases using MR imaging.

## METHODS

The findings in this study were obtained by retrospectively analyzing the T2 sequences of non-contrast axial orbital and cranial MR images acquired at Ankara Training and

Research Hospital and Erzincan Binali Yıldırım University Faculty of Medicine over the past 5 years. Ethics committee approval was received for this study from the ethics committee of Ankara City Hospital No. 2 Clinical Research Ethics Committee (Date: May 26, 2021, Number: E2-21-1456). Approval was obtained from the hospital management where patient data was used. Included in the study were 426 patients (213 males and 213 females). Patients were separated into 5 distinct age-based groups: group 1: birth-1-year-old; group 2: 1-3 years old; group 3: 3-5 years old; group 4: 6-12 years old; group 5: 12-18 years old.

Two radiologists with years of experience 9 and 11 made measurements from 3 separate segments of the optic nerve in axial T2 sections. In the pediatric group, patients with a history of brain tumor, orbital tumor, hamartomatous lesion, optic nerve atrophy, elevated intracranial pressure, and brain, temporal, and skull bone malformations were excluded from the study.

## Experimental Design

Magnetic resonance imaging machines of 1.5-T (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) typically use T1- and T2-weighted sequences to image the orbits. For T1-weighted imaging, a fast spin-echo sequence is often used, while a T2-weighted sequence with a high resolution is used to acquire the images. The parameters for this sequence may vary depending on the specific MRI machine being used. 1.5 Tesla Siemens magnetic resonance (MR) include a time to repeat (TR) of 3000-4000 ms, a time to echo (TE) of 100-120 ms, and a slice thickness of 3-4 mm with no gap between slices. The field of view is adjusted to include the entire optic nerve and surrounding tissues. A dedicated head coil is often used for imaging the orbits. This type of coil provides a high signal-to-noise ratio and spatial resolution, allowing for detailed visualization of the structures within the orbits.

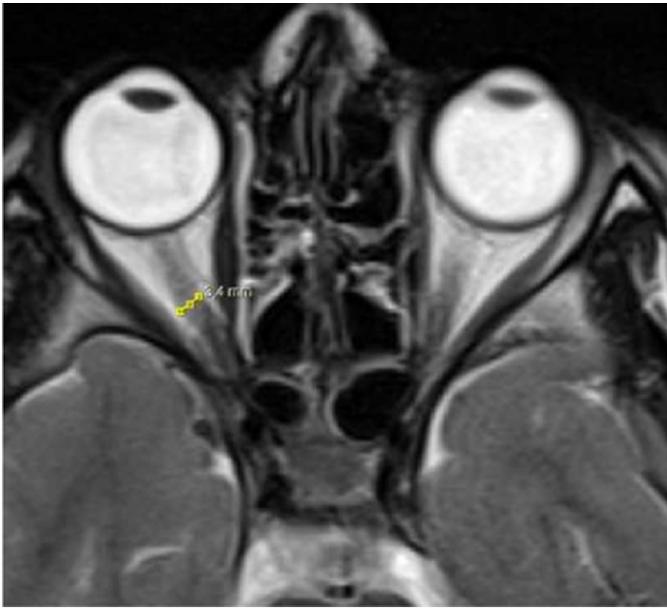
According to age groups, 426 participants were retrospectively scanned, and normal measurements were acquired at orbital (Figure 1), prechiasmatic (Figure 2), and optic tract levels (Figure 3) and recorded as final results.

## Statistical Analysis

STATA 13 was utilized for each statistical analysis (StataCorp, College Station, Tex, USA). The outcomes were provided as mean  $\pm$  SD. To verify the dependability and reproducibility of the results, intraclass correlation coefficients and 95% CIs were used to evaluate interclass agreement. After confirming agreement between the 2 raters, the right or left eye was examined using the paired Student's *t* test or Wilcoxon signed-rank test, and the differences between sexes were analyzed using the unpaired *t* test or the Mann-Whitney *U*-test. Analysis of variance testing was done to uncover between-group differences,

### MAIN POINTS

- Using MR imaging, determine the normal values of the optic nerve in different segments of the nerve trace in normal pediatric patients.
- The evaluation of diseases in different segments of the optic nerve in pediatric patients may be facilitated by the use of normal measures from these segments.
- The measurement values obtained by 2 radiologists from 3 distinct segments were consistent.

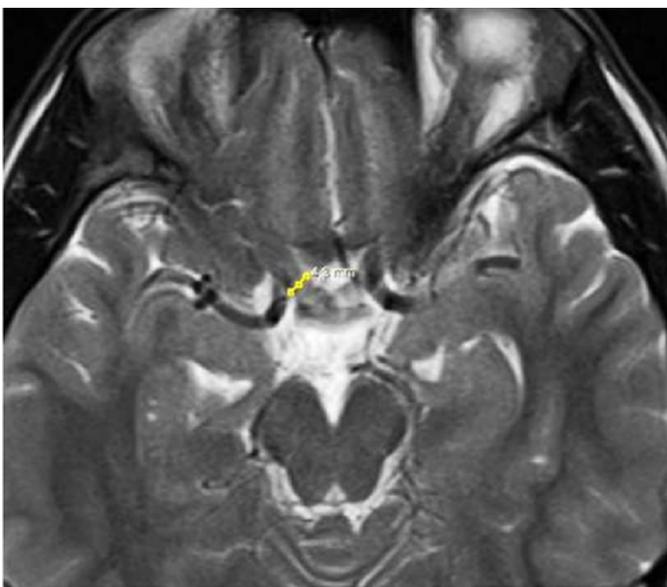


**Figure 1.** Five-year-old male, axial T2-weighted image showing measurement of optic nerve at intraorbital portion. OP, orbital plane.

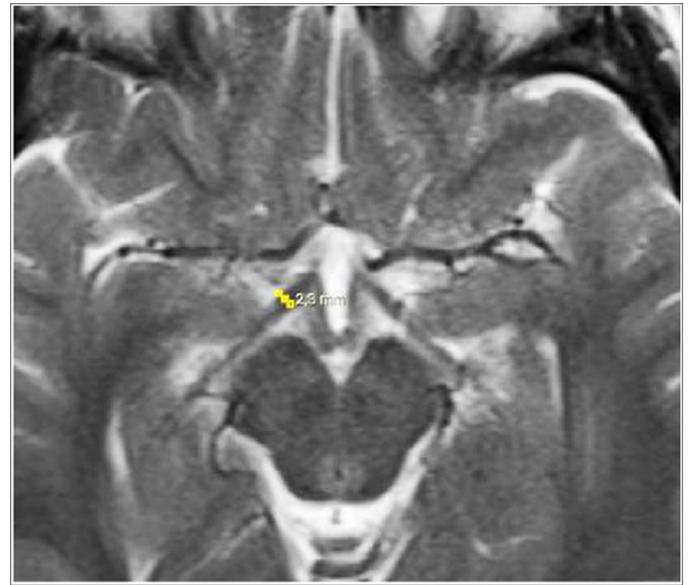
with a Sidak correction for multiple comparisons applied for more specific results about confidence intervals and significances between each age group. The measurement findings were then plotted against age, and Pearson or Spearman correlation coefficients were determined.

## RESULTS

Two radiologists with 11 and 9 years of experience retrospectively scanned and assessed 426 MRI examinations of



**Figure 2.** Three-year-old female, axial T2-weighted image showing measurement of optic nerve at prechiasmatic portion (PP).



**Figure 3.** Ten-month-old male, axial T2-weighted image showing measurement of optic nerve at optic tract (OT).

pediatric patients. The median age was  $8.31 \pm 5$  years. Two hundred thirteen patients were male and 213 patients were female. Interrater reliability was great. They were assessed in 5 distinct age groups: 46 images within the 0-1 age range; 70 images of children aged 1-3; 60 images of children aged 3-5; 100 images of children aged 6-12; and 150 images from the 12-18 age group. In all groups, the number of girls and boys was equal.

In the study, measurements were taken from the orbital plane (OP). The mean optic nerve diameter was 3.5 mm (2.4-4.9 mm) in children aged 0-1; 3.8 mm (2.5-5.1 mm) in children aged 1-3; 4.0 mm (2.8-5 mm) in children aged 3-5; 5.3 mm (3-6 mm) in children aged 6-12; and 5.5 mm in the 12-18 age group. There was no substantial difference between girls and boys ( $P > .05$ ).

In the study, measurements were taken from the prechiasmatic plane (PP). The mean optic nerve diameter was 4.5 mm (3.4-5.9 mm) in children aged 0-1; 4.8 mm (3.5-6.3 mm) in children aged 1-3; 5.0 mm (3.5-5.2 mm) in children aged 3-5; 6.3 mm (4-6.5 mm) in children aged 6-12; and 6.5 mm in the 12-18 age group. There was no substantial difference between girls and boys ( $P > .05$ ).

In the study, measurements were taken from the optic tractus (OT) plane. The mean optic nerve diameter was 3.7 mm (2.2-4.2 mm) in infants aged 0-1 years; 3.9 mm (2.8-5.6 mm) in children aged 1-3 years; 4.3 mm (2.9-5 mm) for children aged 3-5 years; 5.3 mm (3-6 mm) for children aged 6-12 years; and 5.7 mm for children aged 12-18 years. There was no substantial difference between girls and boys ( $P > .05$ ).

**Table 1.** The Values Obtained by Both Observers in Different Measured Segments According to Their Respective Age Groups

Age Group	PART	N	Mean (mm)	SD (mm)	95% CI (mm)
Group 1 (0-1 year) (mean: 8.3 months)	OP	46	3.5	0.53	2.4-4.9
	PP	46	4.5	0.48	3.4-5.9
	OTP	46	3.9	0.48	2.8-5.6
Group 2 (1-3 years) (mean: 2.3 years)	OP	70	3.8	0.63	2.5-5.1
	PP	70	4.8	0.58	3.5-6.3
	OTP	70	4.3	0.51	2.8-5.6
Group 3 (3-5 years) (mean: 4.2 years)	OP	60	4.3	0.23	2.8-5
	PP	60	5	0.42	3.5-5.2
	OTP	60	4.3	0.12	2.9-5
Group 4 (6-12 years) (mean: 8.3 years)	OP	100	5.3	0.41	3-6
	PP	100	6.3	0.34	4-6
	OTP	100	5.7	0.35	3-5.6
Group 5 (12-18 years) (mean: 12.4 years)	OP	150	5.5	0.38	3.1-6
	PP	150	6.3	0.43	4-6.5
	OTP	150	5.7	0.34	3.1-5.

OP, orbital plane; OTP, optic tractus plane; PP, prechiasmatic plane.

The data presented in the previous paragraph was summarized in Table 1.

The average diameter of the orbital section was  $3.58 \pm 0.53$  mm,  $4.74 \pm 0.48$  mm for the prechiasmatic segment, and  $3.61 \pm 0.48$  mm for the optic tract segment across all age groups. Age correlated positively with the OP, PP, and OT values ( $P < .05$ ). All age groups had considerably varying mean OP, PP, and OT diameters ( $P < .05$ ). For all 3 diameters, the interobserver reliability of measurements was satisfactory (kappa values, OP=0.62, PP=0.58, OT=0.67).

## DISCUSSION

The optic nerve is a vital structure responsible for carrying visual information from the retina to the brain. The measurement of optic nerve size is important in the diagnosis and management of various optic nerve pathologies, such as optic neuritis, optic nerve gliomas, and papilledema. Tumors, inflammation, or vascular lesions can affect the optic chiasm, resulting in visual field defects (most commonly bitemporal hemianopia) and vision loss. The most common cause of chiasmal disorders is pituitary adenomas, which can compress the optic chiasm.<sup>11</sup> Optic tract lesions can result from trauma, ischemia, tumors, or demyelination. These lesions typically present with homonymous hemianopia, which is a visual field loss on the same side in both eyes. The affected side is contralateral to the lesion.<sup>12</sup>

Magnetic resonance imaging is a non-invasive modality that can provide accurate measurements of optic nerve size in pediatric patients.

Several studies have reported on the normal measurements of the optic nerve in the pediatric population using MRI. The measurements are often reported as the optic nerve diameter or the cross-sectional area of the nerve at a specific location along its course. The measurements may vary depending on the technique used, such as the type of MRI sequence, the location of the measurement, and the age of the patient.

One study by Avery et al.<sup>13</sup> measured the optic nerve diameter in 28 healthy children aged 5-17 years using T2-weighted fast spin-echo MRI. The study reported a mean optic nerve diameter of 3.0 mm in the right eye and 2.9 mm in the left eye. The optic nerve diameter was found to increase with age and was larger in boys than in girls.

Another study by Wang et al.<sup>14</sup> measured the optic nerve cross-sectional area in 92 healthy children aged 7-14 years using T2-weighted MRI. The study reported a mean optic nerve cross-sectional area of  $7.10 \text{ mm}^2$  in the right eye and  $6.82 \text{ mm}^2$  in the left eye. The study also found that the optic nerve cross-sectional area increased with age and was larger in boys than in girls.<sup>14</sup>

In a study by Duan et al.,<sup>15</sup> the optic nerve cross-sectional area was measured in 56 healthy children aged 3-12 years using diffusion tensor imaging MRI. The study reported a mean optic nerve cross-sectional area of  $5.86 \text{ mm}^2$  in the right eye and  $5.63 \text{ mm}^2$  in the left eye. The optic nerve cross-sectional area was found to increase with age and was larger in boys than in girls.

In contrast to previous research, we evaluated the optic nerve from its orbital, prechiasmatic, and optic tract portions in our investigation. The measurement values in each of the 3 zones were distinct. Consistent with previous research in 5 distinct age groups, measurement values increased with age. The mean diameter of OP in the whole population is  $3.58 \pm 0.53$  mm, PP  $4.74 \pm 0.48$  mm, and OT  $3.61 \pm 0.48$  mm. Age and OP, PP, and OT values are positively correlated. The mean diameters of OP, PP, and OT are significantly different between all age groups. The interobserver reliability of the measurements was good for all 3 diameters (OP kappa value of 0.62, PP kappa value of 0.58, and OT kappa value of 0.67). Our research not only identifies disorders in the orbital region at an early stage, but it also establishes reference values for prechiasmatic and optic tract segments and leads to the early diagnosis of potential pathologies. In this regard, it includes reference values for different portions of the optic nerve, in addition to the results of previous research.

There are limitations to our research. First, MRI measurements of the optic nerve can be affected by factors such as head position and motion, which can lead to inaccuracies in the measurements. For young children, sedation may be necessary to ensure accurate measurements. Additionally, measurements may be influenced by factors such as myopia and optic nerve abnormalities, which can affect the appearance of the optic nerve on MRI.

Furthermore, MRI is not the most sensitive or specific method for detecting early changes in the optic nerve and may not be able to detect subtle changes in the optic nerve that can be seen with other imaging modalities such as OCT. Optical coherence tomography is a higher-resolution imaging modality that can provide more detailed images of the optic nerve head and surrounding tissues than MRI.

Finally, MRI may not be as widely available or accessible as other imaging modalities and may be associated with higher costs and longer wait times for imaging.

In conclusion, several studies have reported on the normal measurements of the optic nerve in the pediatric population using MRI. The measurements are often reported as the optic nerve diameter or the cross-sectional area of the nerve at a specific location along its course. These measurements can serve as a useful reference for the diagnosis and management of various optic nerve pathologies in the pediatric population.

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**Informed Consent:** Approval was obtained from the hospital management where patient data was used.

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**Author Contributions:** Concept – Ö.K., T.Ç.; Design – Ö.K., D.C.Ş.; Materials – Ö.K.; Data Collection and/or Processing – Ö.K.; Writing Manuscript – Ö.K.; Critical Review – E.F.

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