International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Analysis of Ganglion Cell Inner Plexiform Layer and Retinal Nerve Fibre Layer Thickness in Children by Optical Coherence Tomography: A Hospital-Based Cross-Sectional Study

Dr. Nagashree B.N[1], Dr. Shruti[2], Dr. Santosh Policepatil[3]

[1]Assistant Professor, Department of Ophthalmology, Shridevi Institute of Medical Sciences and Research Centre, Tumkur, Karnataka, India.
[2]Senior Resident, Department of Ophthalmology, Yadgir Institute of Medical Sciences (YIMS), Yadgir, Karnataka, India.
[3]Consultant Ophthalmologist, Megur Eye Care Centre, Bidar, Karnataka, India.

OPEN ACCESS

Corresponding Author:

Dr. Shruti
Senior Resident, Department of Ophthalmology, Yadgir Institute of Medical Sciences (YIMS), Yadgir, Karnataka, India.

Received: 10-03-2026
Accepted: 15-04-2026
Available online: 30-04-2026

ABSTRACT

Background: Optical coherence tomography (OCT) provides objective, non-invasive, high-resolution cross-sectional imaging of the retinal nerve fibre layer (RNFL) and the ganglion cell inner plexiform layer (GCIPL). Established normative databases exist for adults, but paediatric reference values remain limited, particularly in the Indian subcontinent. The present study aimed to determine normative RNFL and GCIPL thickness values in healthy Indian children aged 6 to 18 years using spectral-domain OCT (SD-OCT) and to evaluate the influence of age, sex and interocular symmetry on these measurements.

Methods: A hospital-based cross-sectional study was conducted in the Department of Ophthalmology at Shridevi Institute of Medical Sciences and Research Centre, Tumkur, Karnataka, India, between October 2024 and December 2025. A total of 102 eyes of 51 healthy children aged 6 to 18 years were prospectively analysed after informed guardian consent and child assent. All participants underwent complete ophthalmic evaluation including best-corrected visual acuity, slit-lamp biomicroscopy, cycloplegic refraction, biometry and dilated fundus examination. Peripapillary RNFL thickness (superior, inferior, nasal, temporal quadrants and average) and macular GCIPL thickness (superior, inferior and mean) were measured using a HUVITZ SD-OCT device. The average of three consecutive scans was used for analysis. Statistical analysis was performed using SPSS version 24.0 with paired and unpaired t-tests, one-way ANOVA and Pearson correlation, considering $p<0.05$ as significant.

Results: The mean age was 11.49±3.40 years; 52.9% were male. The mean average GCIPL thickness was 75.59±6.20 µm (superior 75.92±5.82 µm; inferior 75.29±6.84 µm). The mean average RNFL thickness was 97.10±6.30 µm, thickest in the inferior quadrant (130.66±11.79 µm) followed by superior (126.42±9.21 µm), nasal (67.81±9.55 µm) and temporal (63.55±8.26 µm), conforming to the classical ISNT pattern. No significant interocular or sex-based differences were observed for either parameter ($p>0.05$). RNFL in the inferior quadrant differed significantly across age groups ($p=0.034$), being thicker in younger children. Pearson correlation showed a significant negative association between age and average RNFL ($r=-0.298$, $p=0.034$) and a non-significant negative trend for GCIPL ($r=-0.239$, $p=0.091$).

Conclusion: This study establishes normative SD-OCT values for GCIPL and RNFL thickness in Indian children aged 6 to 18 years. These reference values may aid the early detection and longitudinal monitoring of paediatric glaucoma, optic neuropathies and other conditions affecting the inner retina.

Keywords: *Ganglion cell inner plexiform layer; GCIPL; Retinal nerve fibre layer; RNFL; Spectral-domain optical coherence tomography; Paediatric; Normative data; Children.*

INTRODUCTION

Optical coherence tomography (OCT) is a non-invasive, non-contact imaging modality that uses low-coherence interferometry to generate high-resolution cross-sectional images of the retina and optic nerve head. Since its first description in 1991, OCT has evolved from time-domain to spectral-domain and, more recently, swept-source technology, with dramatic improvements in axial resolution, scanning speed and reproducibility.[1] Contemporary spectral-domain OCT (SD-OCT) devices offer axial resolution of approximately 3 to 5 microns, permitting quantitative segmentation of individual retinal layers and reliable measurement of peripapillary retinal nerve fibre layer (RNFL) thickness and macular ganglion cell inner plexiform layer (GCIPL) thickness.[2,3]

The peripapillary RNFL, composed of unmyelinated retinal ganglion cell axons converging at the optic nerve head, is one of the earliest structures to be affected in glaucoma and in a variety of optic neuropathies. Similarly, the macular GCIPL, which comprises the cell bodies and dendrites of retinal ganglion cells in the perifoveal region, is highly sensitive to inner retinal injury and often demonstrates measurable thinning before functional visual field loss is detectable.[2,4] Together, RNFL and GCIPL measurements form the structural cornerstone of contemporary glaucoma diagnostics and are increasingly used to monitor a wide range of optic and retinal disorders.[5]

In the paediatric population, the clinical assessment of optic nerve integrity is considerably more challenging than in adults. Standard functional tests such as automated perimetry and colour vision testing require sustained attention and cooperation that many young children cannot reliably provide, and repeatability of subjective testing is generally poor.[6,7] Objective, rapid, non-contact modalities such as SD-OCT are therefore particularly valuable in this age group. SD-OCT has been shown to be feasible in children as young as 4 to 5 years, with high scan acquisition rates and image quality that approaches that seen in adults.[3,8]

Despite the growing use of OCT in children, commercial devices are supplied with normative databases derived almost exclusively from adults older than 18 years. Extrapolating adult reference values to children can be misleading, because paediatric optic nerve heads are less cupped, RNFL tends to be thicker than in older adults, and there are documented associations between OCT parameters and age, refractive error and axial length that may operate differently during the years of ocular growth.[9,10] Consequently, deviations that appear abnormal on the adult chart may in fact reflect a normal paediatric pattern, and conversely subtle paediatric pathology may be missed when it falls within the adult reference range.

A series of studies over the last two decades have sought to characterise normative RNFL and GCIPL values in healthy children of various ethnic backgrounds. Salchow and colleagues reported a mean global RNFL thickness of 107.0±11.1 µm in ninety-two healthy children aged 4 to 17 years and observed a relationship with refractive error.[2] Turk and colleagues examined 107 healthy Turkish children and reported topographic RNFL and macular data using SD-OCT.[3] Barrio-Barrio and colleagues subsequently compiled a multicentre Spanish normative database in 301 Caucasian children aged 4 to 17 years,[4] while Yanni and colleagues used Spectralis SD-OCT to derive layer-specific normative reference ranges in North American children.[5] Al-Haddad and colleagues extended these observations to a Middle Eastern paediatric cohort using Cirrus SD-OCT.[8] More recently, dedicated GCIPL normative data have been reported in Korean children using swept-source OCT[11] and in Swedish children using swept-source technology,[9] both underscoring the fact that GCIPL values are systematically influenced by the segmentation algorithm, device platform and population studied.

Reports from the Indian subcontinent remain scarce. Pawar and colleagues provided one of the earliest Indian paediatric normative datasets using time-domain Stratus OCT in 120 children, reporting an average RNFL thickness of 106.11±9.5 µm with the classical thickest-inferior, thinnest-temporal quadrantic pattern.[6] The same group later demonstrated excellent interocular symmetry of RNFL and optic nerve head parameters in Indian children, supporting the use of a single-eye reference in clinical practice.[12] Rao and colleagues used SD-OCT in Indian children under 18 years and highlighted the strong influence of axial length and refractive error on the recorded values.[13] However, comparatively few Indian studies have simultaneously reported both RNFL and macular GCIPL parameters with a device-specific normative database, and even fewer have examined the influence of age category and sex within the school-going age range using contemporary SD-OCT platforms.

A recent systematic review by Banc and Ungureanu emphasised that paediatric OCT normative data are heterogeneous, with substantial between-study differences attributable to the OCT platform used, the segmentation software, sample selection and ethnic composition of the cohort.[14] The authors concluded that device- and population-specific normative

databases are essential before OCT parameters can be applied to children with suspected optic nerve disease. This is particularly pertinent for newer SD-OCT platforms that are being introduced into clinical practice in India but whose normative databases have not been rigorously validated in Indian children.

The utility of paediatric normative RNFL and GCIPL data extends well beyond the diagnosis of childhood glaucoma. Objective structural measurement of the inner retina is increasingly used in the monitoring of optic pathway gliomas, hydrocephalus and idiopathic intracranial hypertension, compressive optic neuropathies, hereditary optic neuropathies, papilloedema, pars planitis, retinal dystrophies and post-surgical changes in children.[10,15] For each of these applications, the ability to distinguish disease-related thinning from age-appropriate physiological variability depends on the availability of robust local reference data.

Against this background, the present study was designed to establish normative peripapillary RNFL and macular GCIPL thickness values in healthy children aged 6 to 18 years attending a tertiary care ophthalmology department in Tumkur, Karnataka, India, using SD-OCT. The study also aimed to examine the influence of age, sex and eye laterality on these OCT parameters and to compare the observed values with previously published paediatric datasets from Indian and international cohorts.

AIMS AND OBJECTIVES

The primary aim of the study was to establish normative values of ganglion cell inner plexiform layer (GCIPL) thickness and retinal nerve fibre layer (RNFL) thickness in healthy Indian children aged 6 to 18 years using spectral-domain optical coherence tomography.

The specific objectives were:

1. To measure and describe the mean superior, inferior and average GCIPL thickness in healthy children aged 6 to 18 years.
2. To measure and describe the mean peripapillary RNFL thickness in the superior, inferior, nasal and temporal quadrants and the average RNFL thickness.
3. To evaluate interocular symmetry of GCIPL and RNFL thickness between the right and left eyes.
4. To assess the influence of sex and age category (6 to 10 years, 11 to 15 years, 16 to 18 years) on GCIPL and RNFL thickness.
5. To determine the correlation of age with average GCIPL and average RNFL thickness in the study population.

MATERIALS AND METHODS

Study design and setting

This was a prospective, hospital-based, cross-sectional observational study conducted in the Department of Ophthalmology of Shridevi Institute of Medical Sciences and Research Centre, Tumkur, Karnataka, India, between October 2024 and December 2025. The study protocol was approved by the Institutional Ethics Committee, and the research adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from the parent or legal guardian of every participant, and age-appropriate assent was obtained from each child before enrolment.

Sample size

Sample size was calculated using the formula for estimating a single population mean with specified absolute precision. Based on a previously reported mean average GCIPL thickness of 71.5±5.35 µm in a paediatric cohort, with a confidence level of 95% (Z=1.959) and an absolute precision of 1.1 µm, the minimum required sample size was 92 eyes. A total of 102 eyes of 51 healthy children who fulfilled the eligibility criteria were recruited during the study period, exceeding the calculated minimum sample size.

Inclusion criteria

Children aged 6 to 18 years attending the outpatient ophthalmology department for refractive assessment or routine ophthalmic evaluation were eligible if they had best-corrected visual acuity compatible with a normal eye examination, absence of any ocular or systemic condition known to affect the retina or optic nerve, and if written parental consent and child assent could be obtained.

Exclusion criteria

Children were excluded from the study if they had any of the following: evidence of macular or optic nerve abnormality, established or suspected glaucoma, refractive error greater than ±3 dioptre spherical equivalent, previous history of ocular surgery, evidence of strabismus or amblyopia, a positive family history of glaucoma, or systemic illnesses known to influence retinal thickness such as type 1 diabetes mellitus or nephrotic syndrome during the study period. Children with poor scan quality, inability to cooperate for OCT imaging or with signal strength below the manufacturer-recommended threshold were also excluded.

Ocular examination

A structured proforma was used to record demographic details, past medical history, drug intake, ocular history and family history of ocular disease. All participants underwent a comprehensive ophthalmic evaluation, which included assessment of distance and near best-corrected visual acuity using Snellen chart, anterior segment evaluation with slit-lamp biomicroscopy, intraocular pressure measurement, cycloplegic refraction, ocular biometry for axial length and dilated fundus examination using direct ophthalmoscopy, indirect ophthalmoscopy and a 90-dioptre non-contact lens.

OCT imaging protocol

Spectral-domain OCT was performed using a HUVITZ SD-OCT platform under dilated conditions. For each eye, peripapillary RNFL thickness was measured using a circular disc scan protocol centred on the optic nerve head, and macular GCIPL thickness was measured using a three-dimensional macular scan protocol. The following RNFL parameters were obtained: full-circle (360-degree) average thickness (RNFL-FC), and mean thickness in each of the superior (RNFL-S), inferior (RNFL-I), nasal (RNFL-N) and temporal (RNFL-T) quadrants. For GCIPL, the mean thickness in the superior and inferior sectors and the average GCIPL thickness were recorded. Three consecutive scans were acquired for each parameter, and the mean of the three scans was used in the analysis. Only scans meeting the manufacturer-recommended signal strength were included; unreliable scans were repeated. All measurements were performed by a single trained operator to minimise inter-observer variability.

Statistical analysis

Data were entered in Microsoft Excel and analysed using IBM SPSS Statistics version 24.0. Categorical variables were expressed as frequencies and percentages, and continuous variables as mean±standard deviation with 95% confidence intervals where applicable. Interocular differences in GCIPL and RNFL parameters were tested using paired t-tests. Comparisons between males and females were performed using unpaired (independent samples) t-tests. Comparisons of GCIPL and RNFL across the three age groups (6 to 10, 11 to 15 and 16 to 18 years) were performed using one-way analysis of variance (ANOVA), with the F statistic reported. Pearson correlation coefficient (r) was used to examine the relationship between age and average GCIPL and average RNFL thickness. A p-value less than 0.05 was considered statistically significant; a p-value less than 0.001 was considered highly significant.

RESULTS

A total of 102 eyes of 51 healthy children were included in the final analysis. The mean age of the study population was 11.49±3.40 years (range 6 to 18 years). Twenty-seven children (52.9%) were male and 24 (47.1%) were female. Most participants (24, 47.1%) belonged to the 11 to 15 years age category, followed by 21 (41.2%) in the 6 to 10 years category and 6 (11.7%) in the 16 to 18 years category. Best-corrected distance visual acuity was 6/6 in 55 eyes (53.9%), 6/9 in 7 eyes (6.9%) and 6/12 in 40 eyes (39.2%), with the 6/12 group reflecting eyes with low refractive error within the eligibility range that improved to 6/6 with refractive correction.

Table 1. Demographic and clinical profile of the study population (n=51 children; 102 eyes).

Parameter	Category	Frequency (n)	Percentage (%)
Age group (years)	6 to 10	21	41.2
	11 to 15	24	47.1
	16 to 18	6	11.7
Sex	Male	27	52.9
	Female	24	47.1
Visual acuity (eyes)	6/6	55	53.9
	6/9	7	6.9
	6/12	40	39.2
Mean age (years)		11.49 ± 3.40	

Table 2. Descriptive statistics of RNFL and GCIPL thickness parameters (n=102 eyes).

Parameter	N	Mean ± SD (µm)	Range (µm)	Min (µm)	Max (µm)
GCIPL superior quadrant	102	75.92 ± 5.82	26.0	69.0	95.0
GCIPL inferior quadrant	102	75.29 ± 6.84	29.0	66.0	95.0
GCIPL mean (sup+inf)	102	75.59 ± 6.20	26.5	67.5	94.0
RNFL superior quadrant	102	126.42 ± 9.21	37	106	143
RNFL inferior quadrant	102	130.66 ± 11.79	54	104	158
RNFL temporal quadrant	102	63.55 ± 8.26	40	50	90
RNFL nasal quadrant	102	67.81 ± 9.55	53	47	100
RNFL average	102	97.10 ± 6.30	28.0	81.0	109.0

As shown in Table 2, the mean average GCIPL thickness across the study population was 75.59±6.20 µm, with very similar values in the superior (75.92±5.82 µm) and inferior (75.29±6.84 µm) sectors. Peripapillary RNFL thickness demonstrated the classical inferior-superior-nasal-temporal (ISNT) topographic pattern, being thickest in the inferior quadrant (130.66±11.79 µm) and thinnest in the temporal quadrant (63.55±8.26 µm). The mean average RNFL was 97.10±6.30 µm.

Table 3. Comparison of GCIPL and RNFL thickness between right and left eyes (paired t-test).

Parameter	Right eye Mean ± SD (µm)	Left eye Mean ± SD (µm)	t value	p value	Inference
GCIPL superior	76.05 ± 6.04	75.79 ± 5.65	0.225	0.822	NS
GCIPL inferior	75.22 ± 6.87	75.36 ± 6.87	-0.102	0.919	NS
GCIPL mean	75.60 ± 6.32	75.59 ± 6.15	0.006	0.996	NS
RNFL superior	125.98 ± 9.38	126.86 ± 9.11	-0.482	0.631	NS
RNFL inferior	130.73 ± 11.79	130.59 ± 11.91	0.058	0.953	NS
RNFL temporal	63.43 ± 8.26	63.67 ± 8.35	-0.143	0.887	NS
RNFL nasal	68.12 ± 9.55	67.51 ± 9.63	0.320	0.750	NS
RNFL average	97.08 ± 6.20	97.13 ± 6.45	-0.036	0.971	NS

There were no statistically significant interocular differences in any GCIPL or RNFL parameter ($p>0.05$ for all comparisons; Table 3). The mean average GCIPL was 75.60±6.32 µm in the right eye and 75.59±6.15 µm in the left eye ($t=0.006$, $p=0.996$). The mean average RNFL was 97.08±6.20 µm in the right eye and 97.13±6.45 µm in the left eye ($t=-0.036$, $p=0.971$). Similarly, quadrantic RNFL and sectoral GCIPL measurements were symmetrical between the two eyes, supporting the use of one-eye data as representative in this cohort. NS denotes not statistically significant.

Table 4. Comparison of GCIPL and RNFL thickness between male and female participants (independent samples t-test).

Parameter	Male Mean ± SD (µm)	Female Mean ± SD (µm)	t value	p value	Inference
GCIPL superior	75.06 ± 5.40	77.16 ± 6.62	-1.249	0.218	NS
GCIPL inferior	73.98 ± 5.84	76.61 ± 7.75	-1.378	0.174	NS
GCIPL mean	74.46 ± 5.54	76.88 ± 6.99	-1.378	0.175	NS
RNFL superior	126.74 ± 9.18	125.13 ± 9.73	0.610	0.545	NS
RNFL inferior	132.48 ± 12.15	128.75 ± 11.31	1.131	0.264	NS
RNFL temporal	64.44 ± 8.96	62.29 ± 7.42	0.928	0.358	NS
RNFL nasal	67.22 ± 7.72	69.13 ± 11.35	-0.707	0.483	NS
RNFL average	97.76 ± 6.24	96.32 ± 6.21	0.824	0.414	NS

None of the GCIPL or RNFL parameters showed a statistically significant difference between males and females (all $p>0.05$; Table 4). Although female participants tended to have marginally higher GCIPL values (mean 76.88±6.99 µm) than males (74.46±5.54 µm), the difference was not significant ($t=-1.378$, $p=0.175$). Similarly, males had marginally higher inferior RNFL (132.48±12.15 µm vs 128.75±11.31 µm; $p=0.264$), but this did not reach statistical significance.

Table 5. Comparison of GCIPL thickness across age groups (one-way ANOVA).

GCIPL sector	Age group (years)	N	Mean ± SD (µm)	Range (µm)	F	p value	Inference
Superior	6 to 10	21	74.43 ± 4.27	69.4 to 87.0			
	11 to 15	24	76.80 ± 5.63	70.2 to 90.0	1.568	0.219	NS
	16 to 18	6	78.73 ± 11.12	71.4 to 95.0			
Inferior	6 to 10	21	73.28 ± 4.38	68.3 to 83.0			
	11 to 15	24	76.74 ± 7.06	66.8 to 92.0	1.486	0.237	NS
	16 to 18	6	75.92 ± 11.76	67.8 to 93.0			
Mean	6 to 10	21	73.78 ± 4.21	68.2 to 85.0			
	11 to 15	24	76.78 ± 6.12	69.4 to 91.0	1.522	0.229	NS
	16 to 18	6	77.25 ± 11.50	69.2 to 94.0			

Across the three age groups, GCIPL thickness in the superior sector was 74.43±4.27 µm (6 to 10 years), 76.80±5.63 µm (11 to 15 years) and 78.73±11.12 µm (16 to 18 years); these differences were not statistically significant ($F=1.568$, $p=0.219$). Similarly, GCIPL in the inferior sector ($F=1.486$, $p=0.237$) and the mean GCIPL ($F=1.522$, $p=0.229$) did not differ significantly across age groups (Table 5).

Table 6. Comparison of RNFL thickness across age groups (one-way ANOVA).

RNFL quadrant	Age group (years)	N	Mean ± SD (µm)	Range (µm)	F	p value	Inference
Superior	6 to 10	21	128.38 ± 7.22	114 to 142			
	11 to 15	24	125.33 ± 10.69	106 to 140	1.970	0.151	NS
	16 to 18	6	120.17 ± 8.91	112 to 134			
Inferior	6 to 10	21	134.24 ± 10.31	108 to 157			
	11 to 15	24	130.25 ± 12.36	108 to 148	3.625	0.034	Sig.
	16 to 18	6	120.33 ± 8.98	110 to 134			
Temporal	6 to 10	21	64.81 ± 10.15	50 to 87			
	11 to 15	24	63.08 ± 6.92	54 to 82	0.826	0.444	NS
	16 to 18	6	60.00 ± 5.22	56 to 70			
Nasal	6 to 10	21	67.57 ± 9.01	53 to 87			
	11 to 15	24	68.92 ± 10.13	55 to 98	0.167	0.847	NS
	16 to 18	6	66.83 ± 10.44	54 to 81			
Average	6 to 10	21	98.76 ± 5.01	89 to 108			
	11 to 15	24	96.93 ± 6.60	82 to 106	3.182	0.051	NS
	16 to 18	6	91.83 ± 6.21	86 to 102			

The inferior quadrant RNFL was the only parameter to show a statistically significant difference across age groups (F=3.625, p=0.034), being highest in the 6 to 10 years group (134.24±10.31 µm) and lowest in the 16 to 18 years group (120.33±8.98 µm). A borderline non-significant reduction with age was also observed for the average RNFL (F=3.182, p=0.051). RNFL values in the superior, temporal and nasal quadrants did not differ significantly across age groups (Table 6).

Table 7. Pearson correlation of age with average GCIPL and average RNFL thickness.

Correlation with age	Pearson r	p value	Direction	Inference
Average GCIPL	-0.239	0.091	Negative	Not significant
Average RNFL	-0.298	0.034	Negative	Significant

Pearson correlation analysis (Table 7) demonstrated a statistically significant negative correlation between age and average RNFL thickness (r=-0.298, p=0.034), indicating that RNFL thickness tended to decrease with increasing age within the paediatric range studied. A negative but non-significant trend was observed between age and average GCIPL (r=-0.239, p=0.091). Overall, the findings suggest that age exerts a modest but measurable effect on RNFL thickness during late childhood and adolescence, whereas GCIPL is relatively stable across the age range examined.

DISCUSSION

The present study establishes normative peripapillary RNFL and macular GCIPL thickness values in a cohort of healthy Indian children aged 6 to 18 years using SD-OCT. The mean average GCIPL was 75.59±6.20 µm, the mean average RNFL was 97.10±6.30 µm, and the quadrantic RNFL distribution followed the classical ISNT pattern (inferior > superior > nasal > temporal). No statistically significant differences were observed between right and left eyes or between male and female participants for any GCIPL or RNFL parameter. Age exerted a significant negative correlation with average RNFL (r=-0.298, p=0.034) and a non-significant negative trend with average GCIPL (r=-0.239, p=0.091).

Comparison of RNFL values with published data

The mean average RNFL value of 97.10±6.30 µm in the present study is broadly consistent with several previously reported paediatric cohorts, particularly those from the Indian subcontinent. In the south Indian population studied by Pawar and colleagues using time-domain Stratus OCT, the average RNFL thickness in 120 children was reported as 106.11±9.5 µm, with the RNFL thickest inferiorly (134.10±16.16 µm) and superiorly (133.44±15.50 µm), and thinnest temporally (70.72±14.80 µm), a topographic pattern identical to that observed in the present study.[6] The slightly lower absolute RNFL values in the present cohort are likely attributable to platform differences, as SD-OCT and TD-OCT devices are known to yield systematically different absolute RNFL measurements even when the same eye is scanned.[8,14]

The multicentre Spanish study by Barrio-Barrio and colleagues, which enrolled 301 healthy Caucasian children aged 4 to 17 years, reported a mean global RNFL thickness of 97.4±9.4 µm using Cirrus SD-OCT, a value that is essentially identical to the 97.10±6.30 µm observed in the present study.[4] Turk and colleagues, in a healthy Turkish paediatric cohort (n=107, age 6 to 16 years) examined with Spectralis SD-OCT, similarly documented a mean RNFL close to 100 µm and confirmed the ISNT distribution.[3] Al-Haddad and colleagues, using Cirrus SD-OCT in 108 Lebanese children aged 6 to 17 years, reported a mean RNFL of 95.6±8.7 µm, again in close agreement with the current findings.[8] Rao

and colleagues, using Cirrus SD-OCT in Indian children under 18 years, likewise reported RNFL values comparable to those found here, and highlighted the effect of axial length and refractive error on the measurements.[13] Salchow and colleagues reported a somewhat higher mean global RNFL of 107.0±11.1 µm using an earlier-generation OCT device in ninety-two children aged 4 to 17 years, a difference again explicable by the platform used.[2]

The topographic distribution of RNFL, with the inferior quadrant the thickest (130.66±11.79 µm) followed by the superior (126.42±9.21 µm), then nasal (67.81±9.55 µm) and finally temporal (63.55±8.26 µm), mirrors the physiological pattern of retinal ganglion cell axon distribution described in normal adult and paediatric OCT literature.[4,5,6,15] This ISNT pattern reflects the anatomical arrangement of axons converging on the optic nerve head, and its preservation in our data supports the validity of the platform used.

Comparison of GCIPL values with published data

Macular GCIPL data in children remain relatively sparse. The mean average GCIPL of 75.59±6.20 µm in the present study falls between the values reported in different paediatric cohorts using different OCT platforms. Lee and colleagues, using swept-source OCT in 127 healthy Korean children (254 eyes) aged 3 to 17 years, reported a mean average GCIPL thickness of 71.5±5.35 µm.[11] Wolf and colleagues, in a Swedish paediatric cohort using swept-source OCT, reported a mean macular ganglion cell layer thickness of 68.0 µm (standard deviation 4.0 µm), noting that GCIPL thickness in children was not significantly related to age or sex within their sample.[9] The methodological point emphasised by both these authors is that GCIPL absolute values are highly device- and algorithm-dependent, and are influenced by the specific segmentation boundaries used (for example, whether the retinal nerve fibre layer is included within the segmented complex).

In healthy adults, Mwanza and colleagues reported an average GCIPL of approximately 83 to 84 µm using the Cirrus HD-OCT platform, together with identifying age, refraction, ethnicity and axial length as significant predictors of GCIPL thickness.[10] Adult values are systematically higher than those seen here, which may partly reflect device differences but is also consistent with the age-related decline of GCIPL thickness that reverses briefly around adolescence in some reports. Dave and colleagues, examining SD-OCT RNFL parameters in Indian children, similarly cautioned against extrapolation of adult reference norms to paediatric populations.[16] Taken together, our value of 75.59±6.20 µm sits reasonably within the paediatric ranges reported globally and provides a useful device-consistent reference for further use in this population.

Effect of age on RNFL and GCIPL thickness

A significant negative correlation between age and average RNFL ($r=-0.298$, $p=0.034$) was observed in the present study, and inferior quadrant RNFL differed significantly across age groups ($F=3.625$, $p=0.034$), being thickest in the 6 to 10 years group (134.24±10.31 µm) and thinnest in the 16 to 18 years group (120.33±8.98 µm). This pattern is broadly consistent with the trend of gradual RNFL thinning with advancing age observed in adult populations, and with reports from paediatric cohorts in which older children within the paediatric age band show marginally thinner RNFL than younger children.[4,6,10] Pawar and colleagues did not find a statistically significant age effect on RNFL in their Indian paediatric cohort using time-domain OCT, but this may reflect the smaller dynamic range of TD-OCT and the influence of refractive error, which they identified as the more powerful determinant.[6] Barrio-Barrio and colleagues also observed subtle age-related variations in RNFL and macular parameters in their large Spanish cohort.[4]

For GCIPL, the observed negative correlation with age ($r=-0.239$) did not reach statistical significance ($p=0.091$), and none of the ANOVA comparisons across age categories were significant. This is consistent with the finding by Wolf and colleagues that GCIPL is relatively stable across childhood in the absence of pathology.[9] Lee and colleagues, in Korean children aged 3 to 17 years, reported that GCIPL was primarily influenced by spherical equivalent and RNFL rather than by chronological age.[11] The banc et Ungureanu systematic review similarly concluded that age effects on paediatric OCT parameters, when present, are modest and heavily dependent on the OCT platform.[14]

Effect of sex and interocular symmetry

No significant sex-related difference in GCIPL or RNFL thickness was observed in the present study. The direction of the observed differences (marginally thicker GCIPL in females, marginally thicker inferior RNFL in males) is similar to some previous reports but did not reach statistical significance in our sample, likely reflecting sample size limitations. Pawar and colleagues, in Indian children, likewise reported no significant sex effect on RNFL,[6] as did Turk and colleagues in Turkish children.[3] Excellent interocular symmetry of all GCIPL and RNFL parameters (all paired $p>0.05$) is in agreement with previous reports demonstrating high right-left concordance of OCT parameters in normal children, including the Indian paediatric cohort of Pawar and colleagues, who reported an interocular correlation of RNFL and optic nerve head parameters strong enough to support single-eye reference values in clinical practice.[12]

Clinical implications

The availability of population-specific, device-specific normative RNFL and GCIPL data in children is critical because commercial OCT platforms provide adult-only normative databases. When adult norms are applied to children, false-positive flags can occur due to physiologically thicker paediatric RNFL, while true early paediatric optic nerve pathology may be missed because it falls within adult reference intervals. The normative data reported here provide a device-consistent reference for children of the study region and may be applied to the assessment of paediatric glaucoma, optic pathway glioma, hydrocephalus, papilloedema, hereditary optic neuropathies and other paediatric optic nerve disorders in which structural OCT parameters are increasingly used for diagnosis and longitudinal monitoring.[5,10,14,15]

Limitations

This study has several limitations. First, the sample was hospital-based and may not fully represent the general paediatric population. Second, the majority of participants belonged to the 11 to 15 years age category, and only six children were in the 16 to 18 years group, limiting the precision of estimates in that subgroup. Third, participants with refractive errors greater than ±3 dioptres were excluded, so the reported values may not directly apply to children with higher refractive errors. Fourth, axial length data, while measured, were not modelled as a covariate in the current analysis. Finally, ethnic composition was homogeneous, so extrapolation to other Indian populations should be undertaken with caution. Future work with larger, community-based samples and multivariable modelling of axial length and refractive error is desirable.

CONCLUSION

This hospital-based cross-sectional study provides normative SD-OCT reference values for peripapillary RNFL and macular GCIPL thickness in healthy Indian children aged 6 to 18 years. The mean average GCIPL thickness was 75.59±6.20 µm and the mean average RNFL was 97.10±6.30 µm, with the classical inferior-superior-nasal-temporal quadrantic RNFL pattern preserved. GCIPL and RNFL parameters were symmetrical between right and left eyes and did not differ significantly by sex. RNFL showed a significant negative correlation with age, and inferior quadrant RNFL was significantly thicker in younger children. GCIPL was relatively stable across the paediatric age range studied. These findings are broadly consistent with data from other paediatric cohorts worldwide while highlighting the need for device-specific and population-specific paediatric OCT norms. The values reported here may serve as a benchmark for the diagnosis and longitudinal monitoring of paediatric glaucoma, optic neuropathies and other disorders affecting the inner retina in Indian children.

REFERENCES

1. Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, et al. Optical coherence tomography. Science. 1991;254(5035):1178-1181.
2. Salchow DJ, Oleynikov YS, Chiang MF, Kennedy-Salchow SE, Langton K, Tsai JC, et al. Retinal nerve fiber layer thickness in normal children measured with optical coherence tomography. Ophthalmology. 2006;113(5):786-791.
3. Turk A, Ceylan OM, Arici C, Keskin S, Erdurman C, Durukan AH, et al. Evaluation of the nerve fiber layer and macula in the eyes of healthy children using spectral-domain optical coherence tomography. Am J Ophthalmol. 2012;153(3):552-559.e1.
4. Barrio-Barrio J, Noval S, Galdós M, Ruiz-Canela M, Bonet E, Capote M, et al. Multicenter Spanish study of spectral-domain optical coherence tomography in normal children. Acta Ophthalmol. 2013;91(1):e56-e63.
5. Yanni SE, Wang J, Cheng CS, Locke KI, Wen Y, Birch DG, et al. Normative reference ranges for the retinal nerve fiber layer, macula, and retinal layer thicknesses in children. Am J Ophthalmol. 2013;155(2):354-360.e1.
6. Pawar N, Maheshwari D, Ravindran M, Ramakrishnan R. Retinal nerve fiber layer thickness in normal Indian pediatric population measured with optical coherence tomography. Indian J Ophthalmol. 2014;62(4):412-418.
7. Lee H, Proudlock FA, Gottlob I. Pediatric optical coherence tomography in clinical practice: recent progress. Invest Ophthalmol Vis Sci. 2016;57(9):OCT69-OCT79.
8. Al-Haddad C, Barikian A, Jaroudi M, Massoud V, Tamim H, Noureddin B. Spectral domain optical coherence tomography in children: normative data and biometric correlations. BMC Ophthalmol. 2014;14:53.
9. Wolf P, Larsson E, Åkerblom H. Normative data and repeatability for macular ganglion cell layer thickness in healthy Swedish children using swept source optical coherence tomography. BMC Ophthalmol. 2022;22(1):109.
10. Mwanza JC, Durbin MK, Budenz DL, Girkin CA, Leung CK, Liebmann JM, et al. Profile and predictors of normal ganglion cell-inner plexiform layer thickness measured with frequency-domain optical coherence tomography. Invest Ophthalmol Vis Sci. 2011;52(11):7872-7879.
11. Lee YP, Ju YS, Choi DG. Ganglion cell-inner plexiform layer thickness by swept-source optical coherence tomography in healthy Korean children: normative data and biometric correlations. Sci Rep. 2018;8(1):10605.
12. Pawar N, Maheshwari D, Ravindran M, Ramakrishnan R. Interocular symmetry of retinal nerve fiber layer and optic nerve head parameters measured by Cirrus high-definition optical coherence tomography in a normal pediatric population. Indian J Ophthalmol. 2017;65(10):955-962.

13. Rao A, Sahoo B, Kumar M, Varshney G, Kumar R. Retinal nerve fiber layer thickness in children <18 years by spectral-domain optical coherence tomography. Semin Ophthalmol. 2013;28(2):97-102.
14. Banc A, Ungureanu MI. Normative data for optical coherence tomography in children: a systematic review. Eye (Lond). 2021;35(3):714-738.
15. Avery RA, Cnaan A, Schuman JS, Trimboli-Heidler C, Chen CL, Packer RJ, et al. Longitudinal change of circumpapillary retinal nerve fiber layer thickness in children with optic pathway gliomas. Am J Ophthalmol. 2015;160(5):944-952.e1.