Optic Disk Size and Optic Disk-to-Fovea Distance in Preterm and Full-Term Infants

Don Julian De Silva,1,2 Ken D. Cocker,3 Gordon Lau,4 Simon T. Clay,5 Alistair R. Fielder,1,3 and Merrick J. Moseley5

PURPOSE. Few studies have assessed optic disk and retinal morphology in infants. Here the optic disk and optic disk-to-fovea distance were measured in preterm and full-term infants in vivo.

METHODS. Optic disk (OD) dimensions and the center-to-center distance between the OD and the macula were measured using digital imaging in infants undergoing routine ophthalmic examinations. Postmenstrual age of the mother at the time of examination ranged from 32 to 50 weeks. From each image, the OD-to-fovea distance (ODF) and the OD height (ODH) and examination ranged from 32 to 50 weeks. From each image, digital imaging in infants undergoing routine ophthalmic examination was used to measure the distance between the OD and the macula were measured using digital imaging in infants undergoing routine ophthalmic examinations. Postmenstrual age of the mother at the time of examination ranged from 32 to 50 weeks. From each image, the OD-to-fovea distance (ODF) and the OD height (ODH) and OD width (ODW) were measured.

RESULTS. In 51 retinal images from 51 infants, mean ± SD values obtained were 4.4 ± 0.4 mm (ODF), 1.41 ± 0.1 9 mm (ODH), and 1.05 ± 0.13 mm (ODW). These dimensions did not change significantly over the age range studied. The mean value for the ratio between ODF and mean OD diameter (ODF/DD) was 3.76.

CONCLUSIONS. Results of this in vivo study suggest that through the optic nerve head diameter increases by more than 50%, only limited growth occurs at the highly organized area of the posterior pole from birth to adulthood. This study discusses the finding of a large-angle kappa in infants and the use of a binocular digital imaging in infants. Here the optic disk and optic disk-to-fovea distance were measured in preterm and full-term infants in vivo. The finding of a large-angle kappa in infants and the use of a binocular digital imaging in infants to measure optic disk size and its distance from the fovea.

MATERIALS AND METHODS

Digital fundus images were selected randomly from infants undergoing routine screening for retinopathy of prematurity and larger infants assessed for other clinical indications at St. Mary’s Hospital (London, UK). The 80° or 130° lens of a digital fundus camera was used (RetCam; Massie Laboratories, Dublin, CA). Images contained no patient-identifiable information of any nature at any time, and the study was performed in accordance with the tenets of the Declaration of Helsinki II. Eyes with congenital abnormalities, retinopathy of prematurity, and intraocular inflammation were excluded from all analyses.

All infants were examined in the neonatal intensive care unit. Infants’ pupils were dilated with 2.5% phenylephrine and 0.5% cyclopentolate eye drops. Before examination, topical anesthesia (proxymetacaine 0.4%) was instilled in both eyes, and an eyelid speculum used. Contact lens coupling fluid (Viscotears; Novartis, Basel, Switzerland) was applied to the cornea, and the camera lens was placed on it.

Images were analyzed with software (Paint Shop Pro version 7.02; www.jasc.com). For each image, the macula was identified by Isenberg’s five stages of macular development, as follows: 0, no pigmentation; 1, partial annular reflex; 2, partial annular reflex; 3, complete annular reflex; 4, foveal pit; 5, foveolar light reflex. Images that were out of focus, decentralized, or without a discernible macula were not used (43 macula images were used).

Points were marked at the superior, inferior, nasal, and temporal edges of the OD and of the macula (Fig. 1). Distances between them, measured in pixels, were calculated using the Pythagorean theory (neglecting any distortion caused by the projection of the camera). Optic disk height (ODH) was measured using the distance between the superior and inferior points on the disk, and optic disk width (ODW) was measured using the temporal and nasal points. The position of the center of the optic disk was calculated as the mean of the four points marked on the perimeter. The position of the fovea was calculated in the same way using the points on the perimeter of the macula. The optic disk center to fovea (ODF) distance could then be measured.

The optic disk was defined by the inner border of the scleral rim surrounding the nerve tissue. Conversion from pixels to millimeters was based on the manufacturer’s calibration of 0.03 mm/pixel for a 130° field-of-view lens scaled appropriately for the field widths of lenses used in the present study: 0.0157 mm/pixel (80° lens) and 0.0306 mm/pixel (130° lens; RetCam; Massie Laboratories). In adult eyes, the correction can be applied to correct optic disk measurements for refractive error when the parameters of axial length, keratometry, and ametropia are known. In infants these calculations are more challenging because gaining the aforementioned measurements is difficult and the eye is continuing to grow. Although assumptions are made to calculate optic disk measurements—globe diameter, radius of geometric center to retinal surface, angle subtended from fovea to optic disk—the quantitative differences in optic disk measurements from independent studies has not been solely attributed to calibration factors.

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From the 1Department of Ophthalmology, Western Eye Hospital, London, United Kingdom; the 2Department of Ophthalmology, Moorfields Eye Hospital, London, United Kingdom; the 3Department of Optometry and Visual Science, City University, London, United Kingdom; and the 4Department of Visual Neuroscience and the 5Photonics Group, Department of Physics, Imperial College London, United Kingdom.

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Corresponding author: Don Julian De Silva, Department of Ophthalmology, Moorfields Eye Hospital, City Road, London EC1V 2PD, UK; drjdlesilva@yahoo.co.uk.
RESULTS

Fifty-one images of left and right eyes from 51 infants were assessed. Of the infants, 55% (28) were boys and 45% (23) were girls. Only one eye was included for each infant, and the best-quality image was selected from right and left eyes. Mean gestational age was $30.1 \pm 4.7$ weeks (range, 23–40 weeks), and mean birthweight was $1153 \pm 470$ g (range, 440–3050 g). Mean postmenstrual age of the mother at measurement was $37.3 \pm 3.3$ weeks (range, 32.2–48.9 weeks).

Mean $\pm$ SD values obtained were: ODH, $1.41 \pm 0.19$ mm; ODW, $1.05 \pm 0.13$; ODF, $4.4 \pm 0.4$ mm (Figures 2–4). Longitudinal measurements were obtained from a subset of eight infants; dimensions did not change significantly over the age range studied (9 weeks). The mean value for the ratio between ODF and mean OD diameter (ODF/DD) was 3.76. A summary of the results, including Isenberg’s stage of macular development and optic disk appearance, are shown in Table 1. The “indistinct” disk margin refers to a change at the optic disk rim that did not represent a scleral ring or a double-ring sign. These changes might have represented other disk morphology, such as tilted disks.

DISCUSSION

We undertook an in vivo imaging study to assess dimensions of the optic disk and fovea in the infant. To date, few studies have assessed optic disk and macular morphology in infants, and those undertaken have been subject to artifacts arising from postmortem fixation.1,6

A random selection of infants undergoing screening for retinopathy of prematurity was assessed. Many of these infants were born prematurely and weighed less than 1.5 kg. It is unknown whether the development of the optic disk and macula in these infants was normal.

Previous studies assessing the dimensions of the optic disk and fovea in the infant include a postmortem study of the optic disk,1 subjective observation of the posterior pole,6 the use of digital neonatal fundus photographs,11 and the use of digitized photographic images from older children who were born before term.2,3 Table 2 summarizes reports of optic disk measurements in infants to date. Rimmer et al.1 reported in postmortem infants younger than 40 weeks’ gestation optic disk heights of $1.10 \pm 0.21$ mm and widths of $0.93 \pm 0.15$ mm. These measurements were taken from formalin-fixed eyes that had been collected over a 20-year period. Our results are consistent with these findings and take into account an estimated 13% nerve shrinkage induced by fixation. Measurements of optic disk height and width from clinical studies are larger than those of postmortem studies. Nerve shrinkage induced by fixation, a white flange of scleral tissue at the disk rim, and

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**FIGURE 1.** Fundus photograph using a digital fundus camera (Retcam 130) with markers denoting superior, inferior, nasal, and temporal points of the disk and macula.

**FIGURE 2.** Optic disk height as a function of postmenstrual age.

**FIGURE 3.** Optic disk width as a function of postmenstrual age.

**FIGURE 4.** Optic disk-to-fovea distance as a function of postmenstrual age.
magnification factors used to calculate disk size have been proposed to explain this discrepancy. The scleral rim was excluded in our measurements of the optic disk.

Table 1: Stage of Macular Development and Optic Disk Appearance

<table>
<thead>
<tr>
<th>Stage of macular development</th>
<th>Mean PMA, wk (range)</th>
<th>Mean Birth Weight, kg (range)</th>
<th>No. of Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = No pigmentation</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 = Pigmentation of the macula</td>
<td>36.1</td>
<td>0.750</td>
<td>1 (2.3)</td>
</tr>
<tr>
<td>2 = Partial annular reflex</td>
<td>36.0 (34.3–40.7)</td>
<td>0.993 (0.660–1.410)</td>
<td>10 (23.3)</td>
</tr>
<tr>
<td>3 = Complete annular reflex</td>
<td>36.4 (35.6–42.4)</td>
<td>1.251 (0.650–2.000)</td>
<td>18 (41.8)</td>
</tr>
<tr>
<td>4 = Foveolar pit</td>
<td>39.4 (34.9–48.9)</td>
<td>1.165 (0.440–3.050)</td>
<td>14 (32.6)</td>
</tr>
<tr>
<td>5 = Foveolar light reflex</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>37.3 ± 3.3</td>
<td>1.153 ± 0.466</td>
<td>43</td>
</tr>
</tbody>
</table>

Optic disk appearance

| Scleral rim                   | 37.7 (33.7–48.9) | 1.193 (0.440–3.050) | 12 (25.5)   |
| No scleral rim                | 36.7 (35.6–41.7) | 1.118 (0.660–1.410) | 8 (15.7)    |
| Double ring sign              | 36.9 (33.7–44.9) | 1.091 (0.650–1.091) | 15 (29.4)   |
| Indistinct                    | —                   | —                       | 16 (31.4)   |
| Total                        | 37.3 ± 3.3         | 1.153 ± 0.466          | 51          |

Table 2: Summary of Optic Disk Measurements in Infants

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Type of Study</th>
<th>Mean Age at Examination (range)</th>
<th>Gestational Age (wk)</th>
<th>No. of Eyes</th>
<th>Horizontal Disk Diameter (mm)</th>
<th>Vertical Disk Diameter (mm)</th>
<th>Mean Disk Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rimmer et al.</td>
<td>Postmortem</td>
<td>—</td>
<td>&lt;40</td>
<td>20</td>
<td>0.93 ± 0.15</td>
<td>1.10 ± 0.21</td>
<td>0.82 ± 0.26</td>
</tr>
<tr>
<td>Hellström et al.</td>
<td>Digital photographs</td>
<td>7 y</td>
<td>(5.1–9.3)</td>
<td>27</td>
<td>Descriptive analysis</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Hellström et al.</td>
<td>Digital photographs</td>
<td>4.8 y</td>
<td>(3.1–9.1)</td>
<td>29.1</td>
<td>39</td>
<td>—</td>
<td>2.80 ± 0.46</td>
</tr>
<tr>
<td>Present study</td>
<td>In vivo digital photographs</td>
<td>(1–9)</td>
<td>30.1 ± 4.7</td>
<td>51</td>
<td>1.05 ± 0.13</td>
<td>1.41 ± 0.19</td>
<td>1.17 ± 0.26</td>
</tr>
</tbody>
</table>

* Data extrapolated from the assessment of preterm children.
was found to have the double-ring sign (23%; Table 1), suggesting that this appearance may be a normal stage of disk development. After birth, the optic disk enlarges by another 50% to reach adult proportions, and we hypothesize the growth of the disk lessens or abolishes the double-ring sign and a reduction in disk growth, as in ONH, results in the preservation of the double-ring sign.

ONH is characterized by a spectrum of severity, and the optic disk may have an almost normal appearance. A number of investigations have been proposed to aid the diagnosis of ONH. These include ultrasonography, axial tomography, electrophysiologic testing, and calculation of the disk macula/disk diameter ratio (DM/DD). Two studies proposed a threshold DM/DD for the diagnosis of OHN in children 2 years of age: a reduction in disk growth, as in ONH, results in the preservation of the double-ring sign.

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This in vivo study of optic disk size and disk-to-macula distance in infants suggests that though the optic nerve head diameter increases by more than 50%, only limited growth occurs at the highly organized area of the posterior pole from birth to adulthood.

References