Physical and Refractive Characteristics of the Eye at Birth and During Infancy

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THE ORBIT

Introduction

Ophthalmologists and pediatricians should be concerned about development of the orbit for two reasons. The first is the cosmetic effect of a malformed orbit on the appearance of the child. The second and more important reason is the effect of a malformed orbit on the state of the eye and brain. An orbit that is too shallow can cause eversion of the eyelids, proptosis, and exposure of the conjunctiva and cornea as well as exotropia (see Chapter 24). Maldevelopment of the orbit can affect the optic canal, which may decrease vision through effects on the optic nerve (see Chapters 12 and 21). Over 30 congenital malformation syndromes that involve the orbit and/or produce microphthalmos have been described. Reciprocally, the state and size of the eye can affect the development and growth of the orbit. There are data in the literature relating the perinatal removal or absence of the eye to impaired orbital growth. Infants requiring enucleation for conditions such as retinoblastoma, trauma to the globe, severe glaucoma, or congenital structural defects including microphthalmos and anophthalmia may require early prosthesis placement, often within the first few weeks of life. In the rapidly developing infantile eye, a replacement of prosthesis may be needed as often as every 2 weeks, especially if expansion of the orbit is desired. Socket development has been reported to be stimulated by the presence of a globe, and the early loss of a globe, produced experimentally in sheep, has been shown to result in a 35% decrease in mature orbital size. Thus, using correctly sized conformers in the developing neonate may ensure adequate conjunctival growth.

Orbital Growth

Between 6 months of gestational age and 18 months following birth, the bony orbit undergoes rapid changes in size and shaped...
Whitnall described the orbital margin to be circular at birth and to remain so until puberty.\textsuperscript{5} Then as the face grows, the vertical diameter of the orbit increases dramatically. Compared with the adult orbit, the orbit at birth has a large flat roof, an increased contribution of the greater wing of the sphenoid bone to the lateral wall, and an anteriorly facing lacrimal sac caused by an accentuated lacrimal crest. The transverse orbital axis of the neonate is more horizontal than is the downward sloping axis of the adult.

However, the palpebral fissures, as opposed to the rapid growth of the orbit, slowly increase in size from early in gestation to term. Sivan and colleagues' as well as Mehes\textsuperscript{7} found the palpebral fissure length to increase 5 mm in the last 10 to 14 weeks of gestation. Similarly, Jones and associates found a 4-mm increase in the last 8 weeks of gestation.\textsuperscript{8} Hymes found a similar infantile growth but also documented a continuous, although slower increase until puberty.\textsuperscript{9} Palpebral fissure length appears to be greater in black than in Hispanic infants.\textsuperscript{10}

With regard to the development of the conjunctival fornixes, there is nearly no information in the literature. However, it has been stated that "the folds of the fornices (in man) are not obvious until the last month of gestation."\textsuperscript{11}

\textit{Laenberget al.} prospectively measured the conjunctival fornix and orbital margin dimensions of 55 term and premature neonates within a week of birth.\textsuperscript{12} The means, standard deviations, and ranges for gestational age, body weight, horizontal and vertical diameters of the orbital margin, horizontal and vertical diameters of the conjunctival fornix, and palpebral fissure width for the group of infants are shown in Table 3-1.

The relationship between conjunctival fornix dimensions, body weight, and gestational age for each infant are indicated in Figures 3-1 and 3-2. Statistically significant correlation coefficients were calculated for both conjunctival fornix horizontal and vertical diameters in relation to weight, as indicated with $P$ values in Figure 3-1. Horizontal and vertical diameters of the conjunctival fornixes were similarly significantly correlated with gestational age (see Fig 3-2).

Figure 3-3 illustrates the relationship between orbital margin and weight. Statistically significant correlation coefficients were found for the infants’ body weight in relation to either orbital margin horizontal or vertical diameter ($P$ values are given). Figure 3-4 similarly depicts the statistically significant correlation between each of these parameters and gestational age. The relation between palpebral fissure width, body weight, and gestational age is given in Figures 3-5 and 3-6; correlation coefficients were statistically significant for these parameters. Statistically significant linear regression equations ($P < .05$) allowing prediction of conjunctival fornix, orbital margin, and palpebral fissure dimensions from weight or gestational age were calculated (Table 3-2).

A comparison of individual ocular parameters with each other revealed statistically sig-
**TABLE 3-2.**
Linear Regression Equations for Neonatal Conjunctival Fornix, Orbital Margin, and Palpebral Fissure Dimensions in Relation to Weight and Gestational Age

<table>
<thead>
<tr>
<th>Gestational Age (wk)</th>
<th>Weight (am)</th>
</tr>
</thead>
</table>

Conjunctival fornix dimensions correlate closely and in a linear fashion with the weight and gestational age of the infant. The growth of the conjunctival fornix also parallels the growth of the palpebral fissure width but only partially correlates with orbital margin dimensions. There appears to be a different growth pattern in the palpebral fissure and conjunctival fornix from that of the orbit.

The overall proportions of the conjunctival fornix in the premature and term neonate (horizontal diameter/vertical diameter ratio, 18/15 mm = 1.2) vary greatly from those established previously for the adult (25/29 mm = 0.9). Conjunctival fornix dimensions correlate closely and in a linear fashion with the weight and gestational age of the infant. The growth of the conjunctival fornix also parallels the growth of the palpebral fissure width but only partially correlates with orbital margin dimensions. There appears to be a different growth pattern in the palpebral fissure and conjunctival fornix from that of the orbit. Similar findings were reported by Hymes who concluded that the palpebral fissure followed slow, general body growth in contrast to the rapid postnatal changes observed in the eye.

The eye is one of the most fully developed at birth. While many changes will occur with maturity, the absolute dimensions of the eye are closer to adult size than are nearly any other organ of the body.

In the prenatal period, the eye grows fastest between the 8th and 14th week. Overall, growth of the eye parallels growth of the embryo until the 30th week, after which it slows down. The sagittal diameter increases from 12 mm at 6 months' gestational age to 17 mm at 8 months' gestational age (Fig 3-7). Postnatally, the eye grows fastest in the first year of life (about 3.8 mm in sagittal diameter) and then at a progressively slower rate until puberty (Table 3-3). Swan and Wilkins found that half the expected total increase over one's entire lifetime in ocular diameter, volume, and surface area occurs by 6 months of age.
TABLE 3-3.
Physical Ocular Characteristics in Preterm and Term Infants Pooled From the Literature*

<table>
<thead>
<tr>
<th>Age</th>
<th>Sagittal Length (mm)</th>
<th>Corneal Diameter (mm)</th>
<th>Refractive Error (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational (wk)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>16.1</td>
<td>8.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>36</td>
<td>16.1</td>
<td>9.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Term</td>
<td>17.6</td>
<td>9.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Postnatal (mo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>18.2</td>
<td>11.1</td>
<td>0.9</td>
</tr>
<tr>
<td>12</td>
<td>20.6</td>
<td></td>
<td>0.9</td>
</tr>
</tbody>
</table>


FIG 3-7.
Relative size of sectioned eyes of a normal premature infant compared with an adult. (Courtesy of Dr. Robert Foos.)
Early studies of the sagittal diameter of the eye gave variable results due to the inclusion of preterm infants with term infants. In 23 term infants, Sorsby and Sheridan found the sagittal diameter to be 17.9 mm. Most studies give a figure of about 18.0 mm for this parameter. At birth, the transverse diameter of the globe is slightly greater than the sagittal (mean, 18.3 mm) and the vertical diameter slightly less (17.3 mm). Males average about 0.2 mm more in each diameter. In premature infants, the sagittal and transverse diameters are nearly identical, while the vertical diameters are uniformly shorter. However, Harayama and colleagues reported in a Japanese study that the sagittal diameter was shorter than the transverse or vertical diameters during fetal life. They also showed that the vertical meridian circumference was shorter than the transverse or meridian circumferences during fetal life. When studied by ultrasonography the sagittal diameter appears shorter than that measured directly in the pathology laboratory. Using ultrasonography, both Larsen and Blomdahl found the mean sagittal ocular diameter of term newborns to be about 16.6 mm (range, 15.3 to 17.6).

The weight of the newborn eye varies from 2.3 to 3.4 gm, and the volume is between 2.20 and 3.25 cc. The scleral surface area is about 828 sq mm.

The Anterior Segment

The corneal diameter in infants is an important clinical parameter. Diagnoses such as infantile glaucoma or microphthalmos often depend on or are influenced by measurements of corneal diameter. In 15 term infants, Blomdahl found the corneal diameter to range from 9.0 to 10.5 mm with a mean of 9.8 mm. At birth, the vertical corneal diameter exceeds the horizontal (10.5 vs. 9.9 mm) according to Sorsby and Sheridan. Newborn females have a corneal diameter 0.3 mm greater than do males. The definition of macrocornea and microcornea should be 2 SD away from the mean, which would be approximately greater than 11.0 and less than 9.0 mm in term infants (others feel the parameters should be 12.5 and 10.0, respectively). The gestational age of the infant must be taken into consideration before declaring the corneal diameter as being abnormally small. In preterm neonates, Sorsby and Sheridan found the corneal diameter to range from 7.5 to 9.2 mm without directly relating the diameter to gestational age. Musarella and Morin examined 37 infants with a mean postconceptual age of 34 ± 2 weeks and found the corneal diameters to average about 8.2 ± 0.5 mm. They found corneal diameter to correlate best with weight and approximate regression relationship to be: corneal diameter = 0.0014 x weight + 6.3 where the corneal diameter is expressed in millimeters and weight in grams.

The corneal curvature is much steeper in infants than in adults. Donzis and colleagues found the corneal curvature to be about 60 Diop ters in a 28-week gestational age infant. At term, the mean curvature was about 51 D. By following a population of premature infants, they found a reduction of about 8 D in corneal curvature in the last 3 months of gestation. Thus, using donor corneas from infants for keratoplasty may cause a significant myopic shift due to the steep curvature, especially in the more premature neonate.

The sclera in neonates has four times the pliability of adult sclera. Therefore, the infant eye has a greater tendency to collapse during intraocular surgery than does the adult eye. The thickness of the sclera in infants is only 0.45 mm, while in adults it is 1.09 mm. Based on scleral stretching experiments, infantile sclera was found to be about half as strong as adult sclera.

The extraocular muscles are much closer to the back of the eye at birth than at any time later in life. Because most of the growth of the sclera is in the posterior portion of the eye, the distance of the extraocular muscles from the posterior pole of the eye increases much more with growth than does the distance from the anterior pole. At birth, the lateral rectus muscle insertion lies just about over the equator, while the insertion of the medial rectus muscle lies only 1 or 2 mm in