

SCIENTIFIC REPORT

Keratometry measurements in preterm and full term newborn infants

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Aim: To evaluate the relation between postconceptional age and birth weight with keratometric values in preterm and full term infants.

Methods: A prospective cross sectional study was performed. The cohort included 99 infants (198 eyes) admitted to the Neonatal and Neonatal Intensive Care Units at Schneider Children's Medical Center of Israel from February to September 2002. Keratometry in the horizontal and vertical meridians was performed in both eyes of each infant by two ophthalmologists using an autokeratometer. The results were evaluated according to: postconceptional age (<32 weeks, 32–36 weeks, >36 weeks) and birth weight (<1500 g, 1501–2500 g, >2501 g).

Results: Corneal curvature measurements decreased progressively with both postconceptional age and birth weight. At <32 weeks, mean (standard deviation) readings were 63.3 (3.2) diopters (D) for the horizontal meridian and 57.3 (2.6) D for the vertical meridian; corresponding values at >36 weeks were 54.0 (3.0) D and 50.7 (2.4) D. In the <1500 g group, mean (SD) readings were 61.3 (3.9) D for the horizontal meridian and 56.0 (2.9) D for the vertical meridian; corresponding values in the >2501 g group were 51.3 (2.1) D and 48.6 (1.8) D.

Conclusions: There is an inverse relation of horizontal and vertical keratometric values with both postconceptional age and birth weight. Highest readings were noted in the babies with the lowest birth weight and youngest postconceptional age. The decrease in corneal dioptric power to normal values is linear and is apparently part of the normal ocular maturation.

Infants born prematurely are at high risk of impaired visual acuity, refractive errors, strabismus, and other ocular problems. Numerous refraction studies in preterm infants have shown a predisposition to childhood myopia very early in life.¹ However, the underlying mechanism is not well understood. Various factors contribute to the refractive status in this population, such as lower depth of the anterior chamber and higher refractive power of the lens.^{1–3} Several early studies also pointed to a possible role of corneal refractive power,^{1,2} which was further substantiated by the keratometry study of Gallo and Fagerholm³ comparing myopic preterm infants and emmetropic and myopic full term infants.

In this study, the relation of the corneal curvature with postconceptional age (PCA) and birth weight (BW) is evaluated in preterm and full term infants.

MATERIALS AND METHODS

The study sample included 99 consecutive infants (198 eyes) admitted to the Neonatal and Neonatal Intensive Care Units

of Schneider Children's Medical Center of Israel from February to September 2000. Exclusion criteria were ROP stage II or higher with plus disease, neurological disease, or any syndromes. PCA was calculated by adding the actual age of the infants at the time of the ocular measurements to the gestational age in weeks, according to the criteria of Dubowitz *et al.*⁶ The ophthalmologic examination was performed after stability was achieved. Infants underwent one examination of each eye by two paediatric ophthalmologists (RF and MS), and only similar measurements by both of them were included in the study. Two drops of localine (benoxinate HCl 0.4%, Fischer Pharmaceuticals, Israel) were instilled, and a neonatal Barraquer wire speculum (Storz Ophthalmic Instruments, USA) was used to open the lids. To ensure that the lid speculum would have no effect on the keratometry readings, we used a dual technique, as follows: localine drops were instilled twice to keep the babies calm and two paediatric ophthalmologists participated in the ophthalmic examination, one holding the baby and gently raising the speculum to prevent pressure on the eye, and the other performing the keratometric examination itself. The cornea was kept moist with balanced salt solution. The corneal curvature was measured in the horizontal and vertical meridians with an autokeratometer (Nidek KM 500, Japan).

The study protocol was approved by the Institutional Ethics Committee (Helsinki), and informed consent was obtained from the parents.

The data were analysed using BMDP.⁷ Analysis of variance (ANOVA) with Bonferroni correction for multiple comparisons was used to compare groups. Pearson's correlation was calculated to determine the correlation between the keratometric values and BW and PCA. A p value of ≤ 0.05 was considered significant.

After applying ANOVA to the data, we performed multiple comparisons. Each pair-wise comparison yielded a p value of < 0.001 for the keratometric measurements by both BW group and PCA group.

RESULTS

There were 52 males and 47 females. Mean gestational age, BW, and PCA are presented in table 1. Mean horizontal and vertical corneal meridians for the right and left eyes are presented in table 2. As no significant differences were detected between the right and left eyes, we used the mean values of both eyes for the analyses. There was a highly significant correlation between the vertical and horizontal meridians ($r = 0.92$, $p < 0.001$).

Table 3 presents the keratometry readings of the horizontal and vertical corneal meridians and the calculated difference between them (ΔHV) by BW and PCA.

Mean (SD) horizontal meridian in the lowest BW group was 61.3 (3.9) diopters (D), and mean vertical meridian, 56.0 (2.9) D. Values were lower in the 1501–2500 g group (horizontal meridian 56.8 (2.3) D, vertical meridian 52.7

Table 1 Study population

	Mean (SD)	Range
Gestational age (weeks)	31.6 (4.4)	24–40
Birth weight (g)	1600 (750)	570–4400
Postconceptional age (weeks)	34.2 (3.9)	24.4–42.8

(1.9) D) and lowest in the >2500 g group (51.3 (2.1) D and 48.6 (1.8) D, respectively) ($p < 0.001$ for both). There was also a significant decline in Δ HV with increase in BW ($p < 0.001$).

Infants less than 32 weeks PCA had high keratometry values; mean horizontal meridian was 63.3 (3.2) D, and mean vertical meridian, 57.3 (2.6) D. Corresponding values in the 32–36 week group were 58.3 (3.0) D and 53.9 (2.5) D, and in the >36 week group, 54.0 (3.0) D and 50.7 (2.4) D ($p < 0.001$ for both). The decline in the mean horizontal and vertical meridians (Δ HV) with age was highly significant ($p < 0.001$).

DISCUSSION

At birth, the globe is larger in its transverse diameter than in its sagittal diameter (mean 18.3 mm); the vertical diameter measures 17.3 mm. In preterm infants, the sagittal and transverse diameters are nearly identical, and the vertical diameters are smaller.

The horizontal and vertical corneal diameters at birth are high (approximately 10 mm) relative to the adult eye, attaining adult size at ages 1–3 years.⁸ The period of most rapid corneal growth is the first six months of life. The newborn cornea is also steeper than the adult cornea, and is usually more curved in its periphery than centrally.⁹ The mean radii of the curvature of the anterior and posterior surfaces of the human cornea are 7.8 and 6.5 mm, respectively, compared with the radius of the external surface of the scleral globe, which measures 11.5 mm. The radii of the corneal curvature translate into a vergence of power of approximately 48.8 D, which accounts for three quarters of the total refractive power of the eye.¹⁰

Many studies on the radius of the corneal curvature in newborns and infants have been published, but the results vary owing to the technical difficulties of using a keratometer while the babies are moving. Ehlers *et al* reported a mean value of 53.13 D for preterm infants, 47.50 D for full term infants, and 43.69 D for children aged 2–4 years.¹¹ Donzis *et al* found the corneal curvature to be about 60 D at 28 weeks' gestational age; at term, the mean curvature was about 51 D.¹² In preterm infants, there was reduction of about 8 D in the corneal curvature in the last three months of gestation. The authors concluded that the radius of corneal curvature reaches adult range at about 3 years of age. Yamamoto *et al*, in a trial to fit a contact lens to newborns, found that the mean corneal curvature of the preterm baby was 50.75 D, and of the full term baby, 48.06 D.¹³ In a study of preterm babies aged 2–12 weeks, Yuji reported a rapid corneal curvature change (from 49.01 to 45.98 D) during the first two to four weeks of life, followed by a deceleration after eight weeks (44.60 D).¹⁴ Regardless of gestational age at birth, the power of the corneal curvature rapidly decreased and reached normal childhood range within 12 weeks.¹⁴ Our results in preterm and term babies are very similar to those of Ehlers *et al*¹¹ and Yamamoto *et al*.¹³ However, in our study we recorded both horizontal and vertical keratometry powers and noted that both BW and PCA played an important role. The lower the BW and PCA, the higher the horizontal, vertical, and Δ HV values.

Hittner *et al*¹⁵ and Gallo and Fagerholm³ found an association between high keratometric values and retinopathy of prematurity (ROP). They emphasised the pathogenic

Table 2 Horizontal and vertical meridians of the right and left eyes

	Right eye (mean (SD))	Left eye (mean (SD))
Horizontal meridian (D)	58.6 (5.0)	58.6 (5.0)
Vertical meridian (D)	53.8 (3.9)	54.2 (3.5)

$p = 0.24$ for right eye v left eye.
 $p < 0.001$ for vertical v horizontal meridian.

importance of high corneal refractive power in the development of myopia in preterm children. However, the relative weight of each of the refractive elements—namely, corneal curvature, depth of the anterior chamber, lens thickness, and axial length—remains controversial.

There is a general consensus that the degree and frequency of myopia are proportional to changes in the cicatricial retinopathy,^{16 17} but there still remains disagreement regarding the refractive abnormalities in eyes in which the ROP disappears spontaneously. Some authors have found that the degree and frequency of myopia in these cases were similar to those in eyes without ROP.^{18 19} Others have claimed that the frequency of myopia was high in preterm infants regardless of ROP.^{20 21} Quinn *et al* found that refractive status in prematurely born infants changed to myopia between the ages of 3 months and 1 year, but not thereafter.²² Therefore, they assumed that in preterm infants, myopia could be predicted by the refractive findings at 3 months of age. In our study, only babies with ROP stage I–II without plus disease were included. Therefore, we did not find an association between ROP stage and keratometric values.

Astigmatism occurs more frequently in the neonatal period than later in life and has a different axis. Fulton *et al* examined 75 infants under 1 year of age and noted astigmatism greater than 1 D in 19%.²³ In a related study,²⁴ they noted a relationship between astigmatism and higher degrees of myopia, and suggested that the more severe larger astigmatism may contribute to the development of myopia by the visual blurring mechanism found in animals. Rutstein *et al* noted that extremely premature infants tended to have more myopia and greater astigmatism than infants born closer to term.²⁵

Fielder *et al* postulated that lower extrauterine temperatures may impede corneal flattening in preterm infants.²⁶ However, other studies have found that normal ocular development and emmetropisation are apparently dependent on regulatory mechanisms in the retina and central nervous

Table 3 Horizontal and vertical corneal meridians by various parameters

	Horizontal meridian (H) (mean (SD))	Vertical meridian (V) (mean (SD))	Δ HV (mean (SD))
Birth weight (g)			
≤ 1,500 (n = 56)	61.3 (3.9)	56.0 (2.9)	5.3 (2.0)
1,500–2,500 (n = 30)	56.8 (2.3)	52.7 (1.9)	4.1 (1.5)
> 2,500 (n = 13)	51.3 (2.1)	48.6 (1.8)	2.7 (1.2)
Significance of difference	$p < 0.001$	$p < 0.001$	$p < 0.001$
Postconceptional age (weeks)			
≤ 32 (n = 32)	63.3 (3.2)	57.3 (2.6)	6.0 (1.8)
32–36 (n = 37)	58.3 (3.0)	53.9 (2.5)	4.4 (1.9)
> 36 (n = 30)	54.0 (3.0)	50.7 (2.4)	3.3 (1.2)
Significance of difference	$p < 0.001$	$p < 0.001$	$p < 0.001$

system.²⁷ Wildsoet and Pettigrew gave chickens intravitreal injections of kainic acid and found that higher doses induced corneal flattening which stopped the myopic shift associated with the expansion of the vitreal chamber.²⁸ Nevertheless, in some of the eyes given a low dose, the corneal steepening caused a myopic shift, which was opposed by the effects of the increase in cornea-lens separation without an accompanying increase in axial length. Therefore, it is possible that in preterm children, the development of retinal lesions leads to similar effects on eye growth and refractive changes. Chemical elements may affect corneal steepening, expansion of the vitreal chamber, and cornea-lens separation.

In conclusion, our study revealed an inverse relationship of horizontal and vertical keratometric readings, and the difference between them, with PCA and BW. Babies with the lowest BW and PCA had the highest keratometric readings. The decrease in corneal dioptric power toward normal values with the increase in BW and PCA is linear, in accordance with other maturation parameters, and it is probably part of the normal ocular maturation process, along with the increase in eyeball dimensions.

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