Biometric Confirmation of the Hirschberg Ratio in Strabismic Children
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PURPOSE. In the Hirschberg eye position test, the ratio of strabismic angle to decenteration of the corneal reflex is dependent on two biometric parameters of the eye: the radius of the corneal curvature and the depth of the anterior chamber. This study was designed to confirm whether the Hirschberg conversion ratio (HR) previously determined for adults can be used for children of various ages despite structural growth of the eye.

METHODS. For 262 eyes of 131 children with strabismus (age range, 6 months to 11 years), the radius of the corneal curvature was measured with an auto-keratometer and the anterior chamber depth with an A-scan ultrasound unit under general anesthesia before the surgery. Using these measurements, the HR was computed on the basis of a geometric model.

RESULTS. The calculated HR was constant across the age range, and the mean ± SD was 19.9 ± 1.9 prism diopters/mm (95% confidence interval, 16.1-23.6 prism diopters/mm). The ratios for the two eyes in each subject showed good correlation (R = 0.854, P = 0.0001). Neither of the biometric measurements was significantly correlated with age, although considerable scatter of the measurements was observed.

CONCLUSIONS. These results indicate that the averaged HR can be applied in children regardless of the patient's age, although intersubject variance of the ratio should be taken into account. (Invest Ophtalmol Vis Sci. 1998;39:2782-2785)

The Hirschberg test, which is a test of strabismic deviation based on the location of a corneal light reflex, is one of the basic techniques used by ophthalmologists. In this test, a conversion ratio is necessary to obtain the strabismic angle (in prism diopters [Δ] or degrees) from the observed dislocation of the corneal reflex (in millimeters). This ratio can be derived by measuring the displacement of the corneal reflex during the change of the subject's fixation on separate targets with known visual angles relative to the subject's eye position. These empirically determined values are almost entirely consistent across investigations (range, 19-22 Δ/mm).

With regard to the geometry of this test, however, the conversion ratio is dependent on two biometric parameters of the eye: the radius of the corneal curvature and the anterior chamber depth. Thus, the ratio has the potential to change with structural development of the eye. If so, one might obtain a false result if the ratio previously determined for adult subjects were used in pediatric patients. This is not a trivial problem because the Hirschberg test is usually used for young children who are uncooperative when undergoing strabismic examinations. Moreover, the problem becomes crucial when this test is performed with the expectation of a high level of precision.

Recently, Riddell et al. reported that the ratio in infants did not differ from that in adults when obtained with the above-cited empirical method. Nevertheless, we feel that this question has not been resolved completely because certain fixation on the target, which is a precondition in such appraisal, is doubtful, especially in young subjects. In this situation, we think that direct measurement of the two biometric parameters could provide a more reliable conversion ratio.

In this study, measuring the radius of the corneal curvature and the anterior chamber depth simultaneously in strabismic children of various ages under general anesthesia, we computed the Hirschberg conversion ratio (HR) on the basis of a geometric model and examined the distribution of the ratios with respect to the children's ages.

METHODS

The subjects were 131 consecutive patients with strabismus who underwent surgery under general anesthesia between 1994 and 1996 at the Hospital of the Okayama University Medical School. There were 65 boys and 66 girls. Their ages ranged from 6 months to 11 years, and the mean ± SD age was 4.0 ± 2.8 years. Their diagnoses included infantile esotropia (n = 64), intermittent exotropia (n = 17), secondary esotropia (n = 11), superior oblique palsy (n = 9), constant exotropia (n = 8), acquired esotropia (n = 7), and "other" (n = 15). No patient had abnormal ocular findings other than strabismus and refractive errors. Informed consent was provided in advance by the patients' legal guardians, who were first given a full explanation of the study purpose and procedures. This research followed the tenets of the Declaration of Helsinki.

Just before the surgical manipulations, biometric measurements were performed with a Barraquer-type wire speculum while the patient was supine under general anesthesia. The radius of the anterior corneal curvature was measured with a handheld auto-keratometer (model KM-500TM; Nidek). A spherical equivalent of the measurements was used as the representative radius of the corneal curvature. The anterior chamber depth was measured using an A-scan ultrasound unit (model AL-010TM; Tomei Medical) with a handheld probe, in the semiautomatic measurement mode. The velocity of sound propagation was set at 1550 m/sec to take into account the slightly greater velocity in the cornea. Special care was taken to align the probe with the visual axis and to minimize corneal appplanation effects.

We took at least five readings from each eye and used the mean of the two values with the highest quality traces as the measurement for computing HR. The repeatability of our measurements was also assessed according to the statistical method.
applied by Zadnik et al. 6 Briefly, we calculated the numeric difference between the two values and analyzed the distribution of those differences (95% limit of agreement within subjects = mean difference ±1.96 × the SD of the differences).

The HR (degrees/mm) was calculated using the following equation, which was derived from the geometric model reported by Brodie1:

\[
HR = \frac{180°}{\pi} \cdot \sin^{-1}\left(\frac{1}{r - de}\right)
\]  

(1)

where \(r\) is the radius (mm) of the anterior corneal curvature and \(de\) is the distance (mm) between the center of the entrance pupil and the apex of the cornea.

The entrance pupil is an image of the actual pupil formed by rays that are refracted by the cornea. The distance between the center of the entrance pupil and the apex of the cornea (\(de\)) is given by the following equation:

\[
de = \frac{1000 \cdot da}{1000 \cdot n - K \cdot da}
\]  

(2)

where \(da\) is the distance (mm) between the center of the actual pupil and the apex of the cornea, and is regarded as equal to the measures of the anterior chamber depth in this study, \(K\) is the measure of the refractive power (diopters) of the cornea, and \(n\) is the refractive index of the aqueous humor, or 1.336. A level of \(P < 0.05\) was considered to be statistically significant.

**RESULTS**

The radius of the corneal curvature was 7.8 ± 0.3 mm (mean ± SD; \(n = 262\) eyes). As Figure 1 shows, there was no correlation between the radius of the corneal curvature and the subject’s age \((R = 0.0001, \text{not significant})\). The repeatability of this measurement (95% limit of agreement within subjects) was ±0.15 mm. The mean anterior chamber depth was 3.2 ± 0.4 mm \((n = 234\) eyes; 28 measurements were omitted because we could not confirm a clear retinal echo, which indicates proper alignment of the A-scan probe). Again, there was no correlation between the anterior chamber depth and the age \((R = 0.0002, \text{not significant})\). The repeatability of this measurement was ±0.38 mm. There was no correlation between the radius of the corneal curvature and the anterior chamber depth \((R = 0.066, \text{not significant})\).

The calculated HR was 19.9 ± 1.9 Δ/mm \((n = 234\) eyes). Figure 2 presents the distribution of the ratio versus age. There was no correlation between ratio and age \((R = 0.0001, \text{not significant})\). The mean HR for patients under 1 year of age was 19.3 Δ/mm \((n = 16\) eyes). When this mean ratio was compared with that of the older age group, 19.9 Δ/mm \((n = 218\) eyes), no difference was found between the ratios (not significant, unpaired t-test).

As shown in Figure 3, there was a significant correlation between the HRs for the two eyes in each subject \((R = 0.854, P = 0.0001)\).

**DISCUSSION**

The HR was constant across the age range of our patients, which confirms the observation of Riddell et al. with the
empirical method. They speculated that the constancy of HR was due to the same rate of increase for the radius of the corneal curvature and the depth of the anterior chamber, such that the increases might cancel each other. However, we did not find any significant fluctuation with age in either of these biometric measurements or correlation between the two measurements.

The previously reported value of the radius of the corneal curvature was $7.8 \pm 0.3$ mm, and that of the anterior chamber depth was $3.2 \pm 0.3$ mm. We did not find any difference between these adult values and those for children. In addition, a longitudinal study of normal infants proved that the radius of the corneal curvature developed rapidly before 4 weeks of age but that the rate of the development decreased by 8 weeks of age and reached the adult value at 12 weeks.

Likewise, Larsen reported little growth of the anterior chamber depth after the age of 2 years and subsequent correlation of age with length of the vitreous cavity. There is still, unfortunately, very little information regarding the growth of the anterior chamber from birth to 2 years of age, probably because of the difficulty of applying the A-scan in non-sedated infants.

Taken together, the previous findings and those of this study suggest that the primary reason for the constancy of the HR is that the growth of the anterior segment of the eye has been almost completed within the first 6 months of life. To verify whether this constancy is invariant in still younger patients does not seem essential from the clinical viewpoint, considering that surgery is performed only occasionally in this age group.

Interestingly, the average HR, 19.9 Å/mm, in this study was slightly smaller than our previous value of 21.8 Å/mm, which was obtained in alert children using the empirical method. Under general anesthesia, an increase in myopia was reported, which implies a decreased depth of the anterior chamber that would reduce the calculated HR. We hypothesize that such a refractive alternation caused by anesthetic agents was responsible for the small discrepancy between our two results.

We found wide variation in the HR, with 95% confidence limits of 16.1 Å/mm to 23.6 Å/mm. The same range of inter-subject variation was reported in some other empirical investigations. Nevertheless, this variation could be explained at least to some extent by random measurement error in the biometry.

The analysis of the repeatability confirmed that the anterior chamber depth measurement was three times more inaccurate than the keratometry. Because the HR is inversely proportional to the difference between the two biometric measurements, as shown in Equation 1 a potential major drawback of our strategy is the error introduced with A-scan measurement. Using a device with similar specifications, Zadnik et al. found that the repeatability of A-scan measurement was ±0.29 mm. Compared with their result, the repeatability of our measurement was slightly poorer. Under general anesthesia, a reduction of intraocular pressure has been reported, and therefore the anterior chamber depth might have been somewhat unstable during our measurements.

However, error propagation analysis showed that less than one fifth of the total variation of the HR is accounted for by random measurement error in the biometry. In addition, the ratios for the two eyes in each subject showed good correlation, which indirectly suggests the validity of the wide intersubject variation of the HR.

In an individual patient, marked deviation of the actual HR from the mean will cause a serious misestimation of strabismic angle if the standard ratio is used. Besides this, especially in patients with large-angle strabismus, peripheral flattening of the corneal curvature also might be a source of the error. In this situation, the result of quantitative surgery may well be other than expected. Eskridge et al. previously recommended the use of higher HR for patients with keratometry readings greater than 46 D and with strabismic deviations greater than 30 prism diopters without any consideration of the variation of the anterior chamber depth. In our study, the fact that we found no correlation between the radius of the corneal curvature and the anterior chamber depth in part supports the opinion of Eskridge et al.

In conclusion, we have clarified that the HR is constant regardless of the patient's age and that its wide intersubject variance limits reliability of this test at present. However, we were able to identify patients with HRs that were quite different from the mean before surgery with biometry performed under general anesthesia.

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References

Cytokine Expression in a Rat Model of Staphylococcus aureus Endophthalmitis

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PURPOSE. To examine the ability of viable Staphylococcus aureus to induce the production of tumor necrosis factor (TNF)-α, interleukin (IL)-1β, cytokine-induced neutrophil chemoattractant (CINC), and interferon (IFN)-γ after intraocular injection.

METHODS. Experimental rat eyes were injected with a 25-μl volume of approximately 80 colony-forming units of viable S. aureus; control eyes received sterile saline. Eyes were graded daily for signs of clinical inflammation and were removed 6, 24, 48, and 72 hours after injection. One group was prepared for histologic analysis, and vitreous was removed from the other group for cytokine analysis, using standard enzyme-linked immunosorbent assay procedures.

RESULTS. TNF-α, IL-1β, CINC, and IFN-γ were detected in experimental vitreous samples at increased levels that peaked at 24 hours. TNF-α, IL-1β, and CINC declined at 48 hours, but IFN-γ remained elevated. At 72 hours, levels could account for the clinical inflammatory response and the entry and decline of vitreous cells in this model of bacterial endophthalmitis. (Invest Ophthalmol Vis Sci. 1998;39:2785-2790)

Staphylococcus aureus is a common cause of postoperative endophthalmitis1 and comprises 99% of the bacterial isolates reported in the Endophthalmitis Vitrectomy Study.2 Endophthalmitis produced by S. aureus, a Gram-positive bacterium, is associated with early onset and a poor visual outcome.1,3 Direct tissue damage by the bacteria and the host inflammatory response are responsible for the tissue destruction associated with endophthalmitis. Cytokines are important host mediators of the inflammatory-immune response, and activation of these responses in the immediate postinfection period is critical in eliminating infectious agents and in decreasing tissue damage. Whole fixed and heat-killed staphylococci and bacterial components (e.g., protein A, lipoteichoic acid, peptidoglycan, and α-toxin) from a variety of Gram-positive bacteria, including S. aureus, have been shown to induce the in vitro production of interleukin (IL)-1, -4, -6, and -8; tumor necrosis factor (TNF)-α, and interferon (IFN)-γ from mononuclear cells, lymphocytes, endothelial cells, and neutrophils.4,5 Therefore, these mediators may be involved in the early phases of endophthalmitis. A principal goal of these studies was to gain knowledge about the local, early host immune response to S. aureus infections of the eye. In particular, we examined the ability of viable S. aureus to induce the production of vitreous cytokines in an established rat model of endophthalmitis.