Ultrasonography in the refraction of aphakic infants

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Modern management of congenital cataracts which interfere with vision consists of early removal of the cataract and correction of the refractive error by contact lenses or glasses (Parks and Hiles, 1967; Von Noorden, Ryan, and Maumenee, 1970).

Skiascopic postoperative refraction of aphakic infants cannot always be performed satisfactorily because the opening is sometimes small and irregular and no reflex can be seen. We, therefore, suggest that refractive error may be determined by calculation from ultrasonographic measurements.

Material and methods

Eleven eyes of seven infants who underwent cataract surgery during 1970 were examined. Details of the patients are given in Table I. The refractive error in each case was determined under general anaesthesia by the two techniques.

Table I *Particulars of seven patients*

<i>Case no.</i>	<i>Sex</i>	<i>Eye</i>	<i>Age at operation (mths)</i>
1	M	Both	14
2	M	Right	9
3	F	Right	18
4	F	Both	4
5	M	Both	36
6	M	Both	6
7	M	Both	5

(1) The axial length of the eye was measured by Time-Amplitude Ultrasonography (TAU). The apparatus was built in our department (by A.S.)

The ultrasonic probe is a plain focused epoxy-encapsulated ceramic transducer. The free resonance of the lead-zirconate-titanate element in air is approximately 7.5 MHz. This provides a near-field of 20 mm. for ocular measurements, which is sufficient to ensure the beam has not spread excessively by the time it is reflected from the posterior wall complex. The diameter of the active surface of the ceramic element is 4 mm., giving a beam divergence of approximately 3°. This transducer geometry fulfills the requirements for ultrasonic ocular biometry, since measurements between 17 and 22 mm. are generally involved.

The probe element is damped with a matching dispersive backing which limits ultrasonic ringing to 7 cycles for 30 db pulse roll-off. The pulse repetition rate is 1,000 pulses per second. A step function waveform with low driving impedance is used to excite the transducer.

The receiver is a wide-band multiple integrated circuit amplifier with full-wave detection and echo processing. The display oscilloscope tube is 5" in diameter. A delayed expandable sweep control is provided. The length is read by comparing the echo position with display markers generated by an internal time-mark generator simultaneously displayed on the oscilloscope face.

From the axial length value thus obtained, the total dioptric power of the eye may be calculated, using the formula

$$F = \frac{n}{f} \times 1,000,$$

when F is the total dioptric power of the eye, n is the global refractive index, and f is the antero-posterior diameter of the eye in millimetres (Emsley, 1952). The corneal curvature was measured by trial contact lens fitting technique, using lenses with a back optic diameter of 8 mm. This procedure can measure the corneal radius of curvature within an error of 0.05 mm. The refractive error was determined by subtracting the dioptric equivalent of the radius of curvature of the cornea measured by the trial contact lens fitting technique from the total dioptric power of the eye (F).

(2) For control purposes, refraction was performed by skiascopy with a trial contact lens of the approximate dioptric power of the eye.

Results (Table II)

The ultrasonographic measurements of the antero-posterior diameter (f) in the eleven eyes were between 20 and 22 mm. By calculation from the formula

$$F = \frac{n}{f} \times 1,000,$$

the total dioptric powers (F) were found to be between +60.50 and +66.75 D.

In ten of the eleven eyes, the radius of corneal curvature was between 7.29 and 7.89 mm. (equivalent of +46.25 and +42.75 D respectively). In one eye the radius was 6.36 mm. (+53 D).

Table II *Refractive error determined by ultrasonographic method*

Case no.	Eye	Ultrasonographically measured antero-posterior diameter (to nearest 0.5 mm.)	Total dioptric power calculated from formula	Corneal curvature		Refractive error
				mm.	diopters	
1	R	22.0	+60.50	7.45	+42.25	+18.25
	L	22.0	+60.50	7.45	+42.25	+18.25
2	R	21.0	+63.50	7.84	+43.00	+20.50
3	R	22.0	+60.50	7.89	+42.75	+17.75
4	R	20.5	+65.00	7.50	+45.00	+20.00
	L	20.0	+66.75	7.58	+44.50	+22.25
5	R	22.0	+60.50	6.36	+53.00	+7.50
6	R	20.0	+66.75	7.71	+43.75	+23.00
	L	20.0	+66.75	7.71	+43.75	+23.00
7	R	22.0	+60.50	7.29	+46.25	+14.25
	L	22.0	+60.50	7.33	+46.00	+14.50

By subtracting the corneal power from the total dioptric power, the refractive error was determined. It was found to be between +14.25 and +23.00 D in ten eyes and +7.50 D in a single eye.

Comparison between the refractive errors measured skiascopically and ultrasonographically (Table III) shows identical results in two eyes (Cases 2 and 5), a difference of half a diopter or less in four eyes, a difference of 0.75 to 1.00 diopters in three eyes, and a difference of 2.25 diopters in both eyes of Case 1.

Table III Comparison of refractive errors as determined by ultrasonography and by skiascopy

Case no.	Eye	Refractive error (to nearest 0.25 D) determined by	
		Ultrasonography	Skiascopy
1	R	+18.25	+16.00
	L	+18.25	+16.00
2	R	+20.50	+20.50
3	R	+17.75	+18.00
4	R	+20.00	+20.50
	L	+22.25	+21.50
5	R	+7.50	+7.50
6	R	+23.00	+24.00
	L	+23.00	+24.00
7	R	+14.25	+14.00
	L	+14.50	+14.00

The Wilcoxon matched-pairs signed ranks test was performed on this data; it established that the differences between the value obtained by the two techniques are not statistically significant ($\alpha = 0.01$; $n = 9$; $T = 18$).

Discussion

Skiascopic determination of the refractive error of aphakic eyes of infants is sometimes difficult or impossible because of small or irregular openings of the posterior lens capsule in the pupillary area. Accurate measurement of the axial length of the eyes enables us to overcome this difficulty.

Since the aphakic eye is a simple optical system in which the cornea is the only refractive surface, it is possible to calculate its total refractive power using the formula, and by subtracting the corneal refractive power from it to determine the necessary prescription.

Since contact lenses create a perfect lacrimo-corneal spherical surface, thus eliminating any astigmatic error, this type of error does not interfere with the calculation and prescription of contact lenses.

The use of TAU for ocular biometry is long established (Mundt and Hughes, 1956; Franken, 1962; Giglio, 1969) in spite of its possible errors (Kimura, Yamazaki, Nakajima, Hayashi, and Nagata, 1969). The errors are mainly due to the presence of the lens, in which the velocity of sound is different from that in the rest of the ocular components (Oksala and Varonen, 1965). This obstacle does not exist, of course, in aphakic eyes. It was previously suggested for aphakic refraction (Elenius and Sopanen, 1963), but is not generally used.

A comparison of the refractive error as calculated from corneal curvature and axial length measurements with that obtained by skiascopic refraction shows no significant differences.

This simple method therefore seems to be adequate for general use in prescribing contact lenses or determining the equivalent spherical measurement in aphakic eyes, especially in infants and children.

Summary

A method of aphakic refraction, using ultrasonographic axial length measurement and contact lens corneal curvature determination, is presented. No significant difference was found when this method was compared with skiascopy in refracting eleven eyes of aphakic infants.

The authors wish to express their appreciation to Mr. George Nissel of London for his contribution towards this research.

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