

Central Corneal Thickness and Glaucoma in Aphakic and Pseudophakic Children

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Background: The risk of glaucoma among aphakic children is as high as 32%, based primarily on intraocular pressure (IOP) measurements. Although IOP may be falsely elevated by increased central corneal thickness, central corneal thickness (CCT) values have not been reported in this population. **Methods:** Patients from the practices of 2 pediatric ophthalmologists and 2 glaucoma specialists had measurements of CCT, IOP, and optic nerve cupping, with visual field analysis when possible. Normal fellow eyes of unilateral aphakes and pseudophakes were included as controls. **Results:** In 36 aphakic and 6 pseudophakic eyes CCT averaged 660 microns compared with 576 microns for phakic fellow eyes ($P < 0.0001$). Glaucoma, defined by IOP at least 35 mm Hg or by IOP at least 22 mm Hg associated with optic nerve changes, occurred in 21% of 28 aphakic patients but in no pseudophakic patient. **Conclusions:** CCT in aphakic/pseudophakic children is substantially increased compared with control patients. These values may be important in interpreting IOP measurements in these children. (J AAPOS 2005;9:326-329)

The risk of glaucoma among aphakic children has been demonstrated to be as high as 32% in previous studies.¹⁻⁴ The glaucoma risk seems lower in pseudophakic children, although their follow-up has been shorter.⁵ The diagnosis of glaucoma in these reports has rested primarily on intraocular pressure (IOP) measurements. Increasing evidence has suggested that IOP may be influenced by central corneal thickness (CCT). Specifically, manometric studies in both humans and animals have found that applanation pressure is likely to overestimate the true IOP as CCT increases.⁶⁻⁹

Although the exact nature of the relationship between corneal thickness and IOP is controversial, many believe that CCT is necessary to interpret applanation tonometry, particularly in eyes with elevated IOPs.⁸ Because corneal thickness has not been reported in aphakic children, we wondered whether these values might be important in evaluating the risk of glaucoma and ocular hypertension (OHT) in these patients years after cataract surgery. We also wanted to reconsider the diagnostic criteria for glaucoma in aphakic children.

PATIENTS AND METHODS

All patients in the active files of 2 pediatric ophthalmologists (J.W.S., J.Z.R.) and 2 glaucoma specialists (S.B.G.,

S.T.S.) with a history of lensectomy in childhood were invited to participate in a prospective study approved by the Albany Medical Center Institutional Review Board. After execution of an informed consent, each child underwent measurement of central corneal thickness using the DGH Technology (Exton PA) 550 Pachette 2 ultrasonic pachymeter. A standard protocol was followed: repeated measurements were taken for each eye in a masked fashion with outlying values eliminated until 12 consecutive values fell within one SD of the mean. In 3 cases, measurements were taken in the course of an examination under general anesthesia that had been scheduled to evaluate IOP. All other measurements were taken without sedation using topical anesthesia. Care was taken to ensure that the probe was placed on the central cornea.

Standard ophthalmologic examinations included assessment of best corrected visual acuity, applanation tonometry, and estimation of optic nerve cupping. Perkins tonometry (Clement Clarke Ltd., London United Kingdom) was used for patients under general anesthesia. Optic nerves were assessed using the direct ophthalmoscope in patients unable to cooperate for biomicroscopy using a 78-D lens. Visual fields were included for patients able to cooperate for this testing. These data were tabulated with CCT values. Also included were the age at lensectomy, type of cataract, eye(s) involved, and history of subsequent vitrectomy or of primary or secondary lens implantation, and prior diagnosis and treatment of OHT or glaucoma. Normal fellow eyes of monocular aphakes and pseudophakes were included as controls. Comparisons of CCT were made using the paired *t*-test.

RESULTS

Patient data are presented in Table 1. A total of 28 patients (42 eyes) underwent lensectomy, 14 (50%) having bilateral

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TABLE 1. Clinical data

Pt. Number	Eye	Procedure	Age at Surg		Age at CCT			Date of			Lens/APH/ Pseudophakia	Glaucoma	Treatment Rx
			(mos)	CCT	(mos)	VA	IOP	T _{max}	T _{max}	ON			
1	OD	L/V	3	600	152	20/15	14	18	2/22/00	0.2	APH	n	n
	OS	L/V	3	612		20/25	14	21	2/22/00	0.2	APH	n	n
2	OD			663	82	20/20	17			0.2	nml	n	n
	OS	L/V	1	698		20/40	17	23	6/23/03	0.2	APH	n	n
3	OD	ECCE w/IOL, V	60	596	196	20/20	12	18	4/29/04	0.1	Pseudo	n	n
	OS	L/V	96	548		20/20	13	16	8/12/02	0.1	APH	n	n
4	OD	L/V	4	712	108	CF	14	26	6/25/04	0	APH	n	n
	OS			595		20/30	13			0.2	nml	n	n
5	OD	L/V	17	623	249	20/20	23	30	10/30/98	0.1	APH	OHT	Dorzolamide/timolol, bimatoprost
	OS	L/V	19	645		20/25	28	34	10/30/98	0.1	APH	OHT	Dorzolamide/timolol, bimatoprost
6	OD			562	8	20/15	14			0.2	nml	n	n
	OS	L/V	1	678		3/300	29	34	5/14/02	0.1	APH	n	n
7	OD	L/V	1	660	26	CSM	6	27	4/24/02	0.1	APH	n	n
	OS	L/V	1	660		CSM	12	25	4/24/02	0.1	APH	n	n
8	OD	L/V, 2° IOL	5 & 144	710	199	20/70	20	22	12/9/03	0.2	Pseudo	n	n
	OS	L/V, 2° IOL	3 & 144	711		20/100	20	22	12/9/03	0.2	Pseudo	n	n
9	OD	L/V	2	690	116	20/70	22	18	3/11/97	0.4	APH	Yes	brimonididne
	OS	L/V	2	835		20/40	29	36	9/8/95	0.7	APH	Yes	timolol, Seton valve
10	OD	L/V, 2° IOL	1	625	12	CSNM	22	22	5/7/04	0	Pseudo	n	n
	OS			536		CSM	10			0	nml	n	n
11	OD			645	134	20/40	16			0	nml	n	n
	OS	L/V	1	737		8/400	22	25	1/26/99	0	APH	n	n
12	OD			578	92	20/25	10			0.2	nml	n	n
	OS	L/V	1 & 24	710		20/25	30	40	7/3/01	0.1	APH	OHT	timolol
13	OD	L/V	1	597	115	20/25	12	22	7/8/04	0	APH	n	n
	OS			572		20/20	12			0	nml	n	n
14	OD			617	47	20/20	16			0	nml	n	n
	OS	L/V	1	695		1/100	12	12	9/4/03	0	APH	n	n
15	OD	L/V	36	599	76	20/300	14	22	1/8/01	ROP	APH	n	n
	OS	L/V (open sky)	7	605		LP	24	24	10/10/03	ROP	APH	n	n
16	OD			564	67	20/25	18			0.2	nml	n	n
	OS	L/V	2	694		20/60	19	34	1/23/02	0.2	APH	OHT	dorzolamide/timolol
17	OD	L/V, 2° IOL	2 & 39	514	46	3/100	16	16	1/12/00	0	Pseudo	n	n
	OS			513		20/20	16			0	nml	n	n
18	OD	L/V	3	623	150	20/200	24	29	4/30/02	0.9	APH	Yes	acetazolamide, latanoprost, multiple trabeculectomies
	OS	L/V	3	602		20/50	27	30	5/2/02	0.5	APH	Yes	acetazolamide, timolol, brimonidine
19	OD	L/V	5	711	72	20/100	30	32	4/16/03	0.7	APH	Yes	dorzolamide/timolol
	OS	L/V	5	581		20/80	19	20	4/16/03	0.4	APH	n	n
20	OD	L/V	2	737	126	20/30	42	50	5/18/99	0.4	APH	Yes	bimatoprost, brimonidine
	OS	L/V		765		20/200	32	45	11/24/02	0.5	APH	Yes	bimatoprost, brimonidine, Seton valve
21	OD			596	152	20/15	16			0.2	nml	n	n
	OS	L/V	1	630		20/25	18	30	7/20/99	0.2	APH	n	n
22	OD			513	67	20/20	12			0	nml	n	n
	OS	L/V	2	596		20/80	12	18	10/28/03	0	APH	n	n

TABLE 1. Continued

Pt. Number	Eye	Procedure	Age at Surg (mos)	CCT	Age at CCT (mos)	VA	IOP	T _{max}	Date of T _{max}	ON	Lens/APH/Pseudophakia	Glaucoma	Treatment Rx
23	OD	L/V	1	696	108	20/20	19	30	2/1/01	0	APH	OHT	trabeculectomy - 3/6/2001
	OS	L/V	2 & 3	695		20/40	24	25	6/30/03	0	APH	n	n
24	OD	L/V	1	759	180	20/50	24	34	8/10/93	0.1	APH	Yes	trabeculectomy × 3
	OS	L/V	1	709		20/30	18	31	8/6/02	0	APH	OHT	dorzolamide/timolol
25	OD	L/V, ectopic lens	48	577	119	CF	14	17	9/8/00	0	APH	n	n
	OS			545		20/20	14			0	nml	n	n
26	OD	L/V, ectopic lens	12	600	75	CF	28	43	5/2/03	0.3	APH	Yes	latanoprost
	OS			562		20/30	15			0	nml	n	n
27	OD	L/V	1	670	142	20/50	19	31	2/28/96	0.1	APH	OHT	brimonidine, dorzolamide/timolol
	OS	L/V		720		20/20	11	37	2/28/96	0.2	APH	Yes	Seton valve
28	OD	ECCE w/IOL, PPV	33	627	103	20/20	18	26	2/3/03	0.2	Pseudo	n	n
	OS	L/V	16	678		20/25	23	20	10/30/00	0.2	APH	n	n
Avg Age			10.15	107.82									
Avg time from surgery to T _{max}			= 82.41 mos.										

L, lensectomy; V, vitrectomy; PPV, pars plana vitrectomy; Pseudo, pseudophakic; ECCE, extra capsular cataract extraction; APH, Aphakic; OHT, ocular hypertension; IOL, intraocular lens implant; CF, counts fingers; LP, light perception; CSM, central, steady, maintained fixation; T_{max}, maximum IOP measure; CSNM, central, steady, not maintained fixation; ROP, retinopathy of prematurity; n, none.

lensectomies and 14 (50%) unilateral lensectomy. Primary lens implantation was performed in eyes 2 patients (2 eyes) and secondary implantation was performed 3 patients (4 eyes). The remaining 23 patients (36 eyes) were aphakic.

Mean CCT values for the aphakic (665 microns, n = 36) and pseudophakic (631 microns, n = 6) eyes were similar ($P = 0.13$), with a combined mean of 660 microns and a range from 514 to 835 microns. In contrast, values for the 14 phakic eyes had a mean of 576 microns and ranged from 513 to 663 microns ($P < 0.001$). Considering only the 14 children who had unilateral surgery, the difference between aphakic/pseudophakic and phakic fellow eyes ranged from 1 to 132 microns, with the operated eye having the higher value in each case. A paired *t*-test showed that corneas in operated eyes were significantly thicker than those in phakic fellow eyes ($P < 0.001$).

Corneas of our pediatric aphakes/pseudophakes also were significantly thicker when compared with reported values for adult (545 microns)^{7,9} and pediatric (555 microns)¹⁰ normals ($P < 0.0001$ for each). The mean CCT of the 14 phakic fellow eyes (576) also was greater than reported adult and pediatric normal patients, but this difference did not reach statistical significance ($P = 0.1318$). Seventeen aphakic eyes of 11 patients had been previously treated for OHT or glaucoma. Treatments, both medical and surgical, are listed in Table 1.

DISCUSSION

Our experience suggests that children with aphakic and pseudophakic eyes are likely to have substantially increased central corneal thickness compared with adult and pedi-

atric control patients. CCT values in these eyes averaged 660 microns and ranged as high as 835 microns compared with phakic fellow eyes, which averaged 576 microns ($P < 0.0001$). We considered these phakic eyes the most appropriate controls for assessing each patient's CCT when only one eye underwent surgery. For bilateral aphakes/pseudophakes, we included both eyes in the study because they represent separate surgical events and permit assessment of inpatient variability. These patients were compared with historical controls.¹¹

It is interesting to speculate as to the cause of the increased corneal thickness. Although all lensectomy procedures were apparently uncomplicated, endothelial cells might have been damaged by unrecognized surgical trauma or other factors. Additionally, endothelial decompensation may have resulted from the irrigating solutions, which contained BSS[®] or BSS Plus[®] (Alcon Laboratories Inc., Fort Worth, TX), Miochol[®] (Novartis Ophthalmics, Duluth, GA), and epinephrine (1:1000,000). Compromise of endothelial function also may have resulted from post-operative inflammation.¹² It also is possible that changes in corneal physiology occurring long after surgery might be responsible. It is noteworthy that none of the eyes studied had clinically identifiable corneal edema and that our measurements were taken years after cataract surgery.

We acknowledge a possible source of bias in our selection of these patients in that they came from glaucoma practices in addition to pediatric ophthalmology practices. However, only one patient was contributed by the glaucoma practices that was not referred by the pediatric ophthalmologists. This child (patient 18) had CCTs of 623

TABLE 2. Ocular hypertension (OHT) and glaucoma in aphakic/pseudophakic children

OHT: IOP 22–35 mm Hg without optic nerve or nerve fiber layer damage or progression, without documented glaucomatous visual field loss.
Glaucoma: IOP 22 mm Hg or greater with optic nerve or nerve fiber layer damage or progression, and/or confirmed glaucomatous visual field loss, or IOP greater than 35 mm Hg.

and 602 in his aphakic right and left eyes, values similar to those of the other patients studied. We also acknowledge that dorzolamide, which was used in the treatment of 5 patients, can theoretically increase corneal thickness. However, the effect of this drug is miniscule compared with the increases we report.¹³

The significantly thicker corneas we report could falsely elevate applanation pressures, as indicated in manometric studies.^{7,8} Although some have extrapolated “corrected pressures” using nomograms or formulas based on CCT, this subject is controversial. The relationship between CCT and IOP is not linear, especially in thick corneas, and published nomograms do not extend into the range of the very thick corneas we encountered.⁷⁻⁹

The appropriate criteria for diagnosing glaucoma in aphakic/pseudophakic children warrant careful consideration. In our original study, glaucoma was defined based on intraocular pressures of at least 26 mm Hg, regardless of optic nerve or visual field changes.¹ We chose this definition because formal visual fields in children are often problematic and careful optic nerve analysis also can be difficult in young children. However, the CCT data we present lead us to question the validity of IOP alone in diagnosing glaucoma.

It is clearly preferable to include measures of structural and functional optic nerve changes in following these patients over time, as suggested by Egbert et al.² Intraocular pressures greater than 22 mm Hg warrant close evaluation of optic nerve and, when possible, nerve fiber layer and visual field changes. Children with such changes clearly have glaucoma. Those without structural or functional changes should receive the diagnosis of OHT unless pressures greater than a certain threshold are noted. Most glaucoma specialists would consider an IOP of 35 mm Hg or greater as sufficiently threatening to warrant the diagnosis of a secondary glaucoma and would begin treatment. These proposed diagnostic criteria are summarized in [Table 2](#).

Using the aforementioned new criteria, we would have diagnosed OHT in 25 of 42 eyes (60%) in 18 of 28 patients (64%). Additionally, we would have diagnosed glaucoma in 9 of 42 eyes (21%) in 6 of 28 patients (21%). Using the old criterion of IOP at least 26 mm Hg, glaucoma would have been diagnosed in the present series in 20 of 36 aphakic eyes (56%) in 15 of 25 aphakic patients (60%). Using the new criteria, the incidence of secondary glaucoma in aphakic children is less than we reported in 1991.¹

We believe that the new criteria give a more realistic prevalence of glaucoma in this population.

One of our 6 pseudophakic eyes (5 patients) had a pressure of 26 mm Hg on one occasion, but none of our other pseudophakes had OHT or glaucoma. Similarly Asrani and associates⁵ noted glaucoma in only 1 of 377 pseudophakic eyes. It must be acknowledged, however, that lens implantation in children has become standard treatment only recently. Follow-up of pseudophakic children has therefore been shorter than that of aphakic children.

Minor elevations in intraocular pressures may be of less concern in children with thick corneas. However, the incidence of glaucoma in aphakic children remains high, regardless of the definition chosen. Indeed, some of our patients had advanced glaucoma, with intraocular pressures as high as 50 mm Hg and cup-to-disk ratios as high as 0.9. Clear progression of visual field loss and optic disk cupping, despite medical and surgical treatment, occurred in some patients.

We believe that aphakic children should have careful and repeated assessments of their IOP, under anesthesia if necessary, and of their optic nerves, nerve fiber layers, and visual fields if possible. If IOP is elevated CCT should be measured to aid in its interpretation.

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