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Original article

Changes of intraocular pressure and refractive status in children following cycloplegic refraction with 1% cyclopentolate and 1% tropicamide☆

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ABSTRACT

Purpose: To evaluate the effect of cycloplegic mydriasis with 1% cyclopentolate and 1% tropicamide on the intraocular pressure (IOP) and refractive status of children for cycloplegic refraction and compare the IOP and refractive changes between hyperopic and myopic groups.

Methods: This study was designed as a retrospective cohort study. Ninety one children received cycloplegic mydriasis. The IOP was measured with a noncontact tonometer before cycloplegic administration. One drop of 1% cyclopentolate was administered, which was followed by two drops of 1% tropicamide at an interval of 10 minutes. The IOP was then measured 30 minutes after tropicamide instillation. Autorefraction was assessed with an autorefractometer before and after cycloplegic mydriasis.

Results: The mean age of the 44 girls and 47 boys was 7.3 ± 2.4 years. The mean precycloplegic IOP was 14.45 ± 2.47 mmHg and the mean postcycloplegic IOP was 15.06 ± 3.08 mmHg in all eyes. A significant difference was noted in the IOP change ($p = 0.033$). In the 39 hyperopic eyes, the mean precycloplegic IOP and postcycloplegic IOP were 14.54 ± 2.53 mmHg and 15.69 ± 3.35 mmHg, respectively. There was a significant difference in the IOP change ($p = 0.008$). In the 52 myopic eyes, the mean precycloplegic IOP and postcycloplegic IOP were 14.38 ± 2.44 mmHg and 14.61 ± 2.80 mmHg, respectively ($p = 0.72$). There was no significant IOP change in the myopic group. The postcycloplegic IOP was significantly different between the hyperopic and the myopic groups ($p = 0.021$). Three eyes (3.3%) had an IOP elevation more than 5.0 mmHg after cycloplegic mydriasis. Postcycloplegic refraction showed significant hyperopic shifts in all eyes ($p < 0.0001$).

Conclusion: Cycloplegic mydriasis with 1% cyclopentolate and 1% tropicamide caused IOP changes in preschool and school-aged children with hyperopia. Ophthalmologists should be very cautious in monitoring IOP changes for children with cycloplegic medication use.

1. Introduction

Cycloplegia is important for young children for performing refractive examinations in a clinical setting. A combination of tropicamide and cyclopentolate is commonly used to achieve maximum pupil dilatation and adequate cycloplegia for measurement of true refractive error in children. Nishizawa et al[1] have reported that the combination drop of 0.5% cyclopentolate hydrochloride and 0.5% tropicamide safely provided satisfactory mydriasis and cycloplegia in 20 minutes, allowing for rapid and accurate examination of the patients. However, cycloplegic agents can induce a significant increase in intraocular pressure (IOP) in the susceptible patients with or without narrow angles.[2,3] Cycloplegics cause significant IOP elevation in 2% of the normal population and up to 23% of patients with primary open angle glaucoma.[4,5] The rise in IOP reached its maximum 45 minutes after instillation of 1% cyclopentolate. Tropicamide has a relatively small effect on IOP in normal eyes as well as those with untreated open angle glaucoma.[5]

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Previous studies have demonstrated that cycloplegics could cause elevation in IOP in adults, but few reports had addressed the IOP changes after cycloplegics in children. We aimed to evaluate the effects of tropicamide and cyclopentolate on IOP in children for cycloplegic refraction and compare the refractive changes after cycloplegia.

2. Methods

2.1. Patients

We conducted a study of children who attended Chang Gung Memorial Hospital, Kaohsiung Medical Center, Taiwan for regular ocular exam and cycloplegic refraction. This study adhered to the tenets of the Declaration of Helsinki. Approval was obtained from the institutional review board and ethics committee at Chang Gung Memorial Hospital. Children between the ages of 3 years and 14 years on the date of examination, with refractive errors between +7.00 and −10.00 diopters (D) with or without astigmatism, and with initial IOP below 21 mmHg were enrolled. Patients who had a history of heart disease, asthma, previous ocular surgery or other ocular diseases, such as congenital cataract, glaucoma, corneal scar and optic neuropathy, were excluded from this study.

2.2. Statistical analyses

All children underwent an ophthalmic examination, including slit-lamp biomicroscopy for anterior segment exam, fundoscopy for macula and optic disc evaluation, noncontact tonometer (TX-F Full Auto Tonometer; Canon, Taichung, Taiwan) for IOP measurement, and autorefractometer (KR-8900; Topcon, Tokyo, Japan) for refraction check-up. Three readings of IOP were taken and the mean IOP was calculated by the machine automatically. IOP and autorefraction were measured in both eyes in all children before cycloplegics administration. One percent cyclopentolate was instilled, which was followed by two doses of 1% tropicamide at an interval of 10 minutes. Autorefraction and IOP were then measured 30 minutes after cycloplegic procedures. Then cycloplegic visual acuity with lens correction was assessed using a Landolt's C chart.

Only right eye data were chosen for statistical calculations. We subcategorized all eyes into hyperopic or myopic group based on their postcycloplegic refractions. The refraction was expressed as spherical equivalence (SE), which was calculated as sphere plus half of the cylinder. The data are presented as mean and standard deviation (SD). The mean values of IOP and SE between the precycloplegia and postcycloplegia were analyzed by the paired sample *t* test among all eyes, hyperopic eyes, and myopic eyes. The differences of age, sex, precycloplegic IOP, and postcycloplegic IOP between hyperopic and myopic groups were compared and analyzed by the independent samples *t* test. A *p* value of less than 0.05 was considered to be statistically significant. We also performed a simple linear regression analysis with precycloplegic IOP, age, sex, and refraction as covariates. All analyses were calculated using SPSS version 17.0 (SPSS, Chicago, IL, USA).

3. Results

Ninety-one children (44 girls and 47 boys) with a mean age of 7.3 ± 2.4 years were included in the study. The mean ages were 5.9 ± 1.6 years and 8.4 ± 2.3 years in the hyperopic and the myopic groups, respectively. There was a significant difference in age between the hyperopic and the myopic groups ($p < 0.0001$). The precycloplegic SE was −1.41 ± 2.41D and the postcycloplegic SE was −0.69 ± 2.54D in all eyes. There was a significant difference between precycloplegic and postcycloplegic refraction ($p < 0.0001$). In the hyperopic group, the precycloplegic SE and postcycloplegic SE were +0.18 ± 1.58D and +1.31 ± 1.60D, respectively. In the myopic group, the precycloplegic SE and postcycloplegic SE were −2.60 ± 2.23D and −2.18 ± 2.05D, respectively. There were significant differences between precycloplegic SE and postcycloplegic SE in both hyperopic and myopic groups (Table 1). A hyperopic shift was noted after cycloplegic mydriasis.

The mean precycloplegic IOP was 14.45 ± 2.47 mmHg and postcycloplegic IOP was 15.06 ± 3.08 mmHg in all children. This change was statistically significant ($p = 0.033$). In the 39 hyperopic eyes, the mean precycloplegic IOP and postcycloplegic IOP were 14.54 ± 2.53 mmHg and 15.69 ± 3.35 mmHg, respectively. There was a significant difference in the IOP change ($p = 0.008$). In the 52 myopic eyes, the mean precycloplegic IOP and postcycloplegic IOP were 14.38 ± 2.44 mmHg and 14.61 ± 2.80 mmHg, respectively. There was no significant IOP change after cycloplegic mydriasis in the myopic group (Table 1). As compared to the precycloplegic IOP and postcycloplegic IOP, there was a significant difference between hyperopic and myopic groups in postcycloplegic IOP ($p = 0.021$; Table 2).

The mean difference of IOP in all children was 0.28 ± 2.22 mmHg. Of all 91 eyes, there were three eyes (3.3%) which had an IOP elevation greater than 5 mmHg, but the IOP reduced (<21 mmHg) after 1 hour without any medical intervention (Table 3). Only one eye had a postcycloplegic IOP greater than 21 mmHg. For the prediction of postcycloplegic IOP, a linear regression analysis using precycloplegic IOP, age, sex, and refraction as covariates did not reveal any significant contribution except for precycloplegic IOP. The linear regression equation for the

Table 1
Differences in intraocular pressure and refraction (spherical equivalence) between pre-cycloplegia and post-cycloplegia in all eyes ($n = 91$), hyperopic eyes ($n = 39$), and myopic eyes ($n = 52$).

	Precycloplegia (mean ± SD)	Postcycloplegia (mean ± SD)	p[a]
All eyes			
IOP (mmHg)	14.45 ± 2.47	15.06 ± 3.08	0.033*
SE	−1.41 ± 2.41	−0.69 ± 2.54	<0.0001*
Hyperopia			
IOP (mmHg)	14.54 ± 2.53	15.69 ± 3.35	0.008*
SE	0.18 ± 1.58	1.31 ± 1.60	<0.0001*
Myopia			
IOP (mmHg)	14.38 ± 2.44	14.61 ± 2.80	0.72
SE	−2.60 ± 2.23	−2.18 ± 2.05	<0.0001*

* Statistically significant ($p < 0.05$).
IOP = intraocular pressure; SD = standard deviation; SE = spherical equivalence.
[a] Calculated by paired sample *t* test.

Table 2
Differences in intraocular pressure and refraction (spherical equivalence) between hyperopic and myopic eyes.

	Hyperopia (mean ± SD)	Myopia (mean ± SD)	p[a]
No. eyes	39	52	
Age (y)	5.9 ± 1.6	8.4 ± 2.3	<0.0001*
Sex (eyes)			0.932
Female	18	26	
Male	21	26	
IOP (mmHg)			
Precycloplegia	14.54 ± 2.53	14.38 ± 2.44	0.677
Postcycloplegia	15.69 ± 3.35	14.61 ± 2.80	0.021*
Refraction (SE)			
Precycloplegia	0.18 ± 1.58	−2.60 ± 2.23	<0.0001*
Postcycloplegia	1.31 ± 1.60	−2.18 ± 2.05	<0.0001*

* Statistically significant ($p < 0.05$).
IOP = intraocular pressure; SD = standard deviation; SE = spherical equivalence.
[a] By independent sample *t* test.

Table 3
Demographic data for patients with intraocular pressure elevation greater than 5 mmHg after cycloplegic mydriasis.

Patient no.	SE (D)	Precycloplegia IOP (mmHg)	Postcycloplegia IOP (mmHg)	IOP elevation (mmHg)
1	+0.25	16.6	22.4	5.8
2	+4.00	12.3	20.6	8.3
3	−2.63	12	17.4	5.4

D = diopters; IOP = intraocular pressure; SE = spherical equivalence.

postcycloplegic IOP was as follows: postcycloplegic IOP = (0.724 × pre-cycloplegic IOP) + 4.284 ($r^2 = 0.38$, $p < 0.0001$).

4. Discussion

Cycloplegic mydriasis can cause an elevation in IOP in normal and open-angle glaucomatous eyes.[4,6–8] Elevation of IOP occurs in the eye which the angle remains open during mydriasis. One possible mechanism for IOP elevation after cycloplegic mydriasis has been related to decreasing aqueous outflow resulting from decreased traction on the trabecular meshwork due to ciliary muscle paralysis.[3,9] Kim et al[6] showed a significant increase in IOP 4–6 hours after cycloplegia with 2.5% phenylephrine and 1% tropicamide in cataract patients. Shaw and Lewis[8] also found that significant IOP elevation occurred in 32% of open-angle glaucoma patients following pupil dilation with 2.5% phenylephrine and 1% tropicamide. Another possible mechanism for IOP elevation after cycloplegic mydriasis is releasing of iris pigment into the anterior chamber and obstruction of the trabecular meshwork.[10,11] Valle[12] had demonstrated IOP elevation of up to 20 mmHg after pupil dilation with 1% cyclopentolate, and all eyes were accompanied by pigment liberation. Kristensen[10] showed that 48% of eyes with open angle glaucoma had an IOP elevation of 8 mmHg or more after pupil dilation, and all IOP elevations were associated with marked pigment release. The other mechanism responsible for IOP elevation is pupillary block. Cycloplegic mydriasis can cause pupillary block and induce elevation of IOP in susceptible subjects. Harris et al[2] found that a narrow angle was a crucial factor that predisposed patients to acute IOP elevation. Previous studies of adult eyes have shown that pupillary block or IOP elevation might occur during physiologic or pharmacological pupil dilation, particularly in the mid-dilated position, at which there is maximum resistance to aqueous flow between the iris and lens.[13,14] In one study of healthy children for annual eye examinations, Tsai et al[15] found that the mean anterior chamber angle, anterior chamber depth, and anterior chamber volume significantly increased following mydriasis in myopic and emmetropic eyes, but they could not find a significant change of IOP after mydriasis. Harris[4] found that 1-2% of healthy persons display a pressure elevation of 6 mmHg or more after pupil dilation with 1% cyclopentolate. Hancox[16] assessed the effect of diagnostic mydriasis with 1% cyclopentolate on IOP of patients attending glaucoma, medical retina and cataract clinics and found that a rise of 5 mmHg or more in 7% of patients. In the present study, we found an IOP elevation in hyperopes after administration of 1% cyclopentolate and 1% tropicamide. The majority of the IOP changes were no more than 5 mmHg except for three eyes (3.3%). One eye was myopic, and the other two were hyperopic. We think that in very young and relatively high hyperopes, the severe tonic spasm of accommodation persists and the pupil size maintains the nearly mid-dilated position, which accompanied by a relatively shorter axial length would cause an IOP elevation after cycloplegic mydriasis. In a Rotterdam follow-up study, high myopia (≤−4D spherical equivalent) was associated with a hazard ratio of 2.31 for the development of incident glaucoma.[17] There was only one myopic eye with IOP change of more than 5 mmHg. Further evaluations in pediatric eyes with a larger population can be carried out to address the relationship between refraction and IOP change after mydriasis.

The IOP was measured with a Goldmann applanation tonometer in adult patients in previous studies.[1,3,5,17] We measured IOP with a noncontact tonometer in young children. Noncontact tonometers measure IOP without touching the cornea, by measuring the time necessary for a given force of air to flatten a given area of the cornea. Modern noncontact tonometers have been shown to correlate well with Goldmann tonometry measurements[18,19] and are particularly useful for measuring IOP in children and for mass glaucoma screenings. Goldmann tonometry and noncontact tonometry are affected by central corneal thickness (CCT). Positive correlations between IOP and CCT are reported in previous studies.[19–23] In the present study, we examined children with noncontact tonometer and found significant IOP difference after mydriasis. Central corneal thickness can be a confounding factor for IOP measurement with a noncontact tonometer in adults, however, its role in the IOP changes of children is not obvious. Further studies can be carried out to address the relation between CCT and IOP changes with cycloplegic agents.

There are some limitations of this study, including the relatively small sample size and the lack of a control group. In the present study, we did not measure CCT, lens thickness, and anterior chamber depth. Further studies regarding lens thickness, anterior chamber depth and IOP were needed to justify the relation between ocular biometric data and IOP after cycloplegic mydriasis in children. We used a noncontact tonometer to measure IOP because it is an easier and faster method for IOP measurement in young children than in adults. Future investigation for IOP measurements between Goldmann tonometers and noncontact tonometers can be carried out to address the IOP difference between various types of tonometers.

In conclusion, there have been few studies focusing on IOP changes after administration of cyclopentolate and tropicamide in children. We reported that cycloplegic mydriasis with 1% cyclopentolate and 1% tropicamide caused IOP changes in children with hyperopia. In Taiwan, we use mydriatics and cycloplegics for cycloplegic refraction in children during their regular ocular examinations. Ophthalmologists should be very cautious in monitoring IOP changes for children with cycloplegic medication use.

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