The Assessment of The Effect of Cycloplegia on Biometric Measurements in Various Age Groups

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ABSTRACT

Purpose: The aim of this study was to assess the effect of cycloplegia by cyclopentolate hydrochloride 1% on biometric measurements obtained by Lenstar LS 900 and intraocular lens (IOL) power calculated by Hoffer Q, Haigis, Holladay 1, Barrett, Olsen and SRK-T formulas.

Material and Methods: The study included 56 eyes of 56 healthy volunteers aged ≤18 years in group 1, 35 eyes of 35 healthy volunteers aged 18-40 years in group 2 and 72 eyes of 72 healthy volunteers aged >40 years in group 3. Topical cyclopentolate hydrochloride 1 % was applied to all volunteers. The biometric measurements were performed by Lenstar LS900 before and after cycloplegia.

Results: The mean age was 12.1±3.6 years (5-17 years) in group 1; 24.6±3.9 years (20-35 years) in group 2; and 56.1±8.8 years (40-73 years) in group 3. Significant differences were detected in lens thickness and anterior chamber depth in all groups after cycloplegia ($p< 0.01$). There were significant differences in IOL power calculated using Olsen formula before and after cycloplegia: 0.13±0.33 D (-0.5 - 1.0 D) in group 1 and 0.21±0.32 D (-0.5 - 1.0 D) in group 2 ($p< 0.01$).

Conclusion: There was no significant difference IOL power calculated using Hoffer Q, Haigis, Holladay 1, Barrett and SRK-T formulas in all groups while there was significant difference in IOL power calculated using Olsen formula in subjects under 40 years old.

Key words: Biometry, Cycloplegia, IOL power.

INTRODUCTION

Currently, biometry is one of the important tools in cataract and refractive surgeries. Optic biometry devices are more commonly preferred since it is a non-invasive, non-contact, rapid and easy to use option which is as effective as immersion ultrasound biometry. Lenstar LS 900 is an optic biometry device based on low-frequency interferometry principle. It is possible to measure axial length (AL), keratometry (K), anterior chamber depth (ACD), white-to-white (WTW) thickness, lens thickness (LT), central corneal thickness (CCT) and pupil diameter by Lenstar LS 900. These measurements are used to calculate intraocular lens (IOL) power in cataract surgery; in addition, they can also be used in refractive surgery and glaucoma. Using Lenstar LS 900 device, it is possible to use third generation formulas including Hoffer Q, Holladay 2, Sanders/Retzlaff/Kraff Theoretical (SRK-T), fourth generations formulas including Haigis, Olsen, Barrett and Masket and Shammas formulas generated to calculate IOL power following refractive surgery. In third generation formulas, effective lens position is estimated using AL and K values while remaining formulas uses more variable.[1, 2]

The cycloplegia is used for diagnostic and therapeutic purposes in all age groups, mainly in children. Cyclopentolate hydrochloride 1% eye drop is one of the most commonly used agents in the assessment refractive errors based on its cycloplegic effect and in ophthalmological examination and treatment based on pupillary dilatation effect e.g. fundus examination, amblyopia (pharmacological penalization) and uveitis treatment. Given the widespread use, biometry measurements can be made after cycloplegia in some situations. There are several studies on effects of cycloplegia on biometric measurements in various age groups.[3-10] In all studies, it was found that there

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was significant increase in ACD measurement while significant decrease in LT measurement after cycloplegia by cyclopentolate hydrochloride 1%. However, results regarding effects of cycloplegia on AL, K, CCT and WTW thickness measurements are controversial. In addition, only a few study investigated effects of cycloplegia on IOL power calculated using relevant formulas. Our study differs from literature by assessment of cycloplegia on biometric measurements and Olsen, Barret formulas in all age groups. The aim of this study was to assess the effect of cycloplegia by cyclopentolate hydrochloride 1% on biometric measurements obtained by Lenstar LS 900 and intraocular lens (IOL) power calculated by Hoffer Q, Haigis, Holladay 1, Barrett, Olsen and SRK-T formulas.

MATERIALS AND METHODS

This prospective study was conducted at Ophthalmology Department. The study was approved by Ethics Committee of University. The study was conducted in accordance to Helsinki Declaration.

The volunteers included were assigned into 3 groups:

Group 1: Healthy volunteers aged ≤18 years who have no disorder other than mild refractive error (spherical equivalent<1.00 D)

Group 2: Healthy volunteers aged 18-40 years who have no disorder other than mild refractive error (spherical equivalent<1.00 D)

Group 3: Healthy volunteers aged ≥40years years have had no disorder other than mild refractive error (spherical equivalent<1.00 D)

The subjects with diabetes mellitus, hypertension or any systemic disease and those with glaucoma, cataract or any ocular disease other than mild refractive error were excluded. In addition, exclusion criteria included history of previous ocular surgery, use of systemic or ocular agents, contact lens use, pregnancy and breastfeeding.

The study included 56 eyes of 56 healthy volunteers group 1, 35 eyes of 35 healthy volunteers in group 2 and 72 eyes of 72 healthy volunteers in group 3. In all subjects, right eyes were evaluated.

In all subjects, cyclopentolate hydrochloride 1% eye drop was given in two occasions by 5-minutes intervals following thorough ophthalmological examination. Biometric measurements were performed using Lenstar LS 900 (Haag-Streit, Koeniz, Siwtzerland) before cycloplegia and 40 minutes after second eye drop administration. In biometric measurements, AL, R1, R2, ACD, WTW, LT and CCT were determined and included to analyses. R1 and R2 values were transformed to diopter values using formula D: 337.5/r and used in analyses as K1 and K2. In addition, we compared to IOL power values calculated using Hoffer Q, Haigis, Holladay 1, Barrett, Olsen ve SRK-T formulas before and after cycloplegia.

Statistical Analysis

Data were analyzed using SPSS version 20.0 Data distribution was assessed using Kolmogorov-Smirnov test. Categorical variables were compared among groups using Chi-square test. The difference among groups was compared using ANOVA test. Using Bonferroni correction, binary comparisons were performed in differences found to be significant. Paired t test was used to compare measurements obtained before and after cycloplegia in each group. In addition, Pearson's correlation coefficient was used to assess relationship between biometric measurement values and age in all groups. A p value<0.05 was considered as statistically significant.

RESULTS

The mean age was 12.1±3.6 years (5-17 years) in group 1; 24.6±3.9 years (20-35 years) in group 2; and 56.1±8.8 years (40-73 years) in group 3. There were 26 male and 30 female in group 1; 19 male and 16 female in group 2; and 40 male and 32 female in group 3 (p=0.56). There was a significant difference in ACD values among 3 groups (p<0.01). In AL values, only significant difference was detected between group 1 and 2 (p<0.01) while only significant difference in astigmatism measurements was detected between group 2 and 3 (p<0.01). In LT measurements, there were significant differences between group 1 and 3 (p<0.01) and between group 2 and 3 (p<0.01). In WTW thickness measurements, there were significant differences between group 1 and 3 (p<0.01) and between group 2 and 3 (p<0.01). There was no significant difference in K1, K2 and CCT measurements among groups (p=0.13, p=0.68 and p=0.06, respectively). In the correlation analyses including whole study population, it was found that there was a strong, positive correlation between age and LT measurement (r=0.75; p<0.01) while a moderate, negative correlation between age and ACD (r=-0.42; p<0.01. The correlations detected were in agreement with larger studies in the literature.[11,12] Among groups, highest mean values for AL, WTW thickness and ACD measurements were observed in group 2. This may be due to higher proportion of male subjects, albeit insignificant, in group 2. In the literature, higher AL and ACD measurements were detected in men compared to women.[11] In addition, it was shown that AU and ACD values were higher in taller individuals.[11] The

difference in group 2 may be due to these factors. Since our study aimed to evaluate effects of cycloplegia on biometric measurements in each age group, the differences among groups were discussed briefly.

Table 1 presents mean AL, K1, K2, ACD, WTW thickness, LT and CCT measurements before and after cycloplegia. Table 2 presents mean IOL power calculated according to Hoffer Q, Haigis, Holladay 1, Barrett, Olsen and SRK-T formulas. There was no significant difference in parameters other than LT, ACD and Olsen IOL power obtained before and after cycloplegia ($p<0.05$).

There were significant differences in LT and ACD measurements obtained after cycloplegia. Mean LT values before and after cycloplegia were 3.55±0.20 mm (3.06-3.97 mm) and 3.44±0.16 mm (3.02-3.82 mm) in group 1; 3.58±0.21 mm (3.07-3.93 mm) and 3.52±0.22 mm (2.98-3.91 mm) in group 2; 4.26±0.41 mm (3.49-5.58 mm) and 4.24±0.42 mm (3.43-5.57 mm) in group 3, respectively. Mean ACD values before and after cycloplegia were 3.52±0.29 mm (2.83-4.08 mm) and 3.64±0.26 mm (3.06-4.13 mm) in group 1; 3.79±0.34 mm (3.07-3.93 mm) and 3.89±0.33 mm (3.30-4.67 mm) in group 2; 3.24±0.35 mm (2.44-3.97 mm) and 3.32±0.35 mm (2.49-4.13 mm) in group 3, respectively. After cycloplegia, mean change in ACD was 0.11±0.7 mm (0.00-0.31 mm) in group 1, 0.09±0.04 mm (0.00-0.21 mm) in group 2 and 0.08±0.04 mm (0.01-0.20 mm) in group 3. Although greatest change was observed in group 1, there was significant difference between group 1 and 3 ($p=0.01$) but not between group 1 and 2 ($p=0.28$). After cycloplegia, mean change in LT was 0.10±0.10 mm (0.00-0.58 mm) in group 1, 0.05±0.05 mm (-0.01-0.24 mm) in group 2 and 0.01±0.02 mm (-0.07-0.10 mm) group 3. The greatest change was observed in group 1 while smallest change in group 2. The differences in all comparisons were significant ($p<0.01$).

After cycloplegia, the IOL power calculated using Olsen formula was significantly higher in group 1 and 2. There were significant differences in IOL power calculated using Olsen formula before and after cycloplegia: 0.13±0.33 D

Table 1. *Mean values before and after cycloplegia in all groups.*

	Group 1			Group 2			Group 3			
	BC	**AC**	***p***	**BC**	**AC**	***P***	**BC**	**AC**	***p***	***P****
AL (mm)	**23.22**±0.91	**23.22**±0.91	**0.28**	**24.30**±0.97	**24.29**±0.97	**0.06**	**23.73**±1.60	**23.54**±2.05	**0.18**	**<0.01**
K 1	**42.80**±1.55	**42.81**±1.54	**0.65**	**42.55**±1.16	**42.55**±1.16	**0.67**	**43.43**±0.58	**43.15**±1.25	**0.37**	**0.13**
K 2	**43.93**±1.50	**42.45**±7.63	**0.15**	**44.11**±1.35	**44.06**±1.40	**0.69**	**43.94**±1.16	**44.34**±0.63	**0.25**	**0.68**
WTW	**12.16**±0.48	**12.13**±0.47	**0.08**	**12.39**±0.40	**12.47**±0.47	**0.08**	**11.89**±0.51	**11.98**±0.42	**0.06**	**<0.01**
LT (mm)	**3.55**±0.20	**3.44**±0.16	**<0.01**	**3.58**±0.21	**3.52**±0.22	<0.01	**4.26**±0.41	**4.24**±0.42	<0.01	<0.01
CCT (µm)	**548.12**±38.62	**546.64**±34.62	**0.33**	**547.45**±34.70	**548.85**±34.13	**0.18**	**527.44**±72.06	**534.43**±34.26	**0.27**	**0.06**
ACD (mm)	**3.52**±0.29	**3.64**±0.26	**<0.01**	**3.79**±0.34	**3.89**±0.33	**<0.01**	**3.24**±0.35	**3.32**±0.35	**<0.01**	**<0.01**

*p value for comparisons of values before cycloplegia among groups
BC: Before cycloplegia, **AC:** After cycloplegia, **AL:** Axial length, **WTW:** White to white thickness, **LT:** lens thickness, **CCT:** Central corneal thickness

Table 2. *Mean IOL power values before and after cycloplegia in all groups.*

	Group 1			Group 2			Group 3		
	BC	**AC**	***P***	**BC**	**AC**	***P***	**BC**	**Ac**	***p***
Hoffer Q (D)	**22.32**±3.09	**22.34**±3.11	**0.64**	**18.67**±2.64	**18.74**±2.67	**0.16**	**20.15**±5.77	**20.44** ±5.09	**0.29**
Haigis (D)	**22.61**±3.07	**22.69**±3.16	**0.10**	**19.02**±2.60	**19.08**±2.62	**0.21**	**20.54**±5.05	**20.68**±5.06	**0.34**
Holliday 2 (D)	**22.28**±2.90	**22.25**±2.98	**0.47**	**18.75**±2.50	**18.78**±2.59	**0.53**	**20.37**±5.09	**20.47**±5.09	**0.47**
Barrett (D)	**22.27**±2.99	**22.36**±3.07	**0.06**	**18.94**±2.53	**18.92**±2.51	**0.71**	**20.47**±4.81	**20.62**±4.80	**0.24**
Olsen (D)	**22.36**±2.91	**22.50**±3.03	**<0.01**	**19.01**±2.57	**19.22**±2.59	**<0.01**	**20.50**±4.82	**20.71**±4.86	**0.16**
SRK-T (D)	**22.20**±2.84	**22.19**±2.78	**0.78**	**18.75**±2.55	**18.78**±2.54	**0.48**	**20.34**±5.05	**20.43**±5.11	**0.45**

BC: Before cycloplegia, **AC:** After cycloplegia, **IOL:** Intraocular lens

(-0.5-1.0 D) in group 1 and 0.21±0.32 D (-0.5-1.0 D) in group 2 ($p< 0.01$).

DISCUSSION

The ACD measurement is important in IOL power estimation and diagnosis of angle closed glaucoma. In addition, in intraoperative planning of cataract surgery, accurate ACD measurement is also important to prevent complications in phakic IOL implantation. There are many studies investigating effects of cycloplegia with cyclopentolate hydrochloride on measurements by different biometry devices in patients aged 3-64 years.[4,10,13] In all studies, a significant increase was detected in ACD measurements after cycloplegia regardless of age group. Mean change varied from 0.05 to 0.28 mm in these studies. In all studies, a significant difference was detected in LT measurements after cycloplegia. The age ranged from 6 to 64 years in subjects included to these studies. Mean age varied from 0.02 and 0.25 mm. These results are in agreement with our results. In our study, there was a significant increase in ACD while a significant decrease in LT in all groups after cycloplegia.

In our study, we compared to IOL power values calculated Hoffer Q, Haigis, Holladay 1, Barrett, Olsen and SRK-T using before and after cycloplegia. In all groups, no significant difference was detected in IOL power values calculated after cycloplegia by formulas other than Olsen formula. After cycloplegia, significant increase was detected in IOL power calculated by Olsen formula in group 1 (≤18 years) and group 2 (18-40 years). The Olsen formula is a fourth generation formula used to calculate IOL power. In fourth generation formulas, effective lens position (ELP) is estimated when calculating IOL power. ELP is not a value that is measured; rather, it is estimated from values obtained in biometric measurements. In the Olsen formula, AL, K, ACD, WTW and LT measurements are used for ELP estimation.[1, 14] In our study, mean change in LT and ACD after cycloplegia was found to be highest in group 1 while lowest in group 3. The significant difference observed in IOL power calculated by Olsen formula in group 1 and 2 seems to be due to greater change in ACD and LT values after cycloplegia.

In the literature, there are several studies investigating effects of pupil dilatation (using tropicamide eye drop) on IOL power calculated by SRK-T, Haigis and Holladay 1 formulas.[15-21] However, only two studies about effects of cycloplegia by cyclopentolate hydrochloride 1% on IOL power calculated using different formulas. In first study, IOL power values calculated by Hoffer Q, Haigis, Holladay 1 and SRK-T formulas before and after cycloplegia were compared.[8] The study included subjects within limited age groups and mean age was 22.1±4.7 years in the subjects. Authors found that IOL power calculated by Haigis formula was significantly higher after cycloplegia. After cycloplegia, the change in IOL power calculated by Haigis formula was within ±1.0 D in whole study population. The change was attributed to changes in ACD parameters used in Haigis formula. In the second study, effect of cycloplegia on IOL power calculated by Haigis, Holladay 1 and SRK-T formulas was investigated in pre-presbyopic and presbyopic individuals.[5] It was found that, after cycloplegia, IOL power calculated by Holladay 1 and Haigis formulas was significantly increased in pre-presbyopic group.

There are many studies investigated effect of cycloplegia on AL measurement. In most studies, no significant difference was detected in AL measurement after cycloplegia in agreement with our study.[4-8,22] Although significant difference was detected in AL measurement after cycloplegia in 2 pediatric studies, the difference was considered to be clinically irrelevant.[9,10] When considered, the difference observed in AL measurement after cycloplegia was within reproducibility limits of devices used.

In studies using optic biometry devices, effect of cycloplegia on keratometry was investigated. In most studies, no significant difference was found in keratometry measurement after cycloplegia in agreement with our study.[3,5,8-10] However, Cheng et al. observed in keratometry measurements after cycloplegia by tropicamide eye drop.[23] Authors attributed this result to lower mean age (9.1±2.8 years) in their study when compared to other study. In our study, mean age was 12.1±3.6 years in group 1 and no significant difference was detected in keratometry measurements after cycloplegia.

There are controversial results in studies on effects of cycloplegia on WTW thickness measurement. In agreement with our study, Momeni-Moghaddam et al. reported no significant effect of on WTW thickness measurement after cycloplegia.[3] On contrary to our study, a significant increase was observed in WTW thickness measurements after cycloplegia in some studies using different optic biometry devices.[4,8,22] Among these, Lenstar LS 900 was used only in one study, reporting mean change of 0.09±0.06 mm in WTW thickness measurement after cycloplegia.[8] In a study on reproducibility of Lenstar device, standard deviation and reproducibility limit for WTW thickness measurements were measured as 0.27 mm and 0.75 mm, respectively.[24] Thus, it is impossible to draw definitive conclusion whether the difference after cycloplegia result from cycloplegia or device.

In many studies, no significant difference was found in CCT measurements after cycloplegia in agreement with our results.[3,71] However, in some studies, a significant increase was detected in CCT measurements after cycloplegia.[9,22] The increase was attributed to reflex hydration caused by eye drop administration rather than corneal edema. In two studies, a significant decrease was detected in CCT measurement after cycloplegia.[5,10]

Our study differs from other studies by including health volunteers from all age groups. Secondly, it is the only study that assessed effects of cycloplegia on IOL power calculated by Barret and Olsen formulas. In addition, this is the first study assessed effects of cycloplegia on IOL power calculated by different formulas in pediatric age groups.

In our study, major limitation is exclusion of individuals with cataract or high refractive error by including only health volunteers. Although number of subjects in groups is relatively smaller, the sample size (n=32) required to detect the difference at alpha value of 0.05 with 80% power was fulfilled in all groups. The use of cyclopentolate hydrochloride as cycloplegic agent and waiting for 40 minutes after application may be considered as limitation in our study since complete cycloplegia could not be achieved 40 minutes after 2 application of cyclopentolate hydrochloride 1%, particularly in those with lighter iris color.[25] However, we used this protocol which is commonly used in the real-life clinical practice since we aimed to assess effects of cycloplegia used in clinical practice on biometric measurements; thus, we did not considered as limitation.

In conclusion, in all age groups, ACD and LT measurements by Lenstar LS 900 biometry device are changed significantly after cycloplegia using cyclopentolate hydrochloride 1% eye drop. No significant difference was detected in IOL power calculated by Hoffer Q, Haigis, Holladay 1, Barrett ve SRK-T formulas in age group while there was significant difference in IOL power calculated by Olsen formula in subjects aged <40 years after cycloplegia.

REFERENCES

1. Turczynowska M,1Koźlik-Nowakowska K, Gaca-Wysocka M, et al. Effective ocular biometry and intraocular lens power calculation. European Ophthalmic Review, 2016;10:94-100.
2. Haigis W, Lege B, Miller N, et al. Comparison of immersion ultrasound biometry and partial coherence interferometry for intraocular lens calculation according to Haigis, Graefes Arch Clin Exp Ophthalmol, 2000;238:765-73.
3. Momeni-Moghaddam H, Maddah N, Wolffsohn JS, et al. The Effect of Cycloplegia on the Ocular Biometric and Anterior Segment Parameters: A Cross-Sectional Study. Ophthalmol Ther. 2019;8:387-95.
4. Arici C, Turk A, Ceylan OM, et al. The effect of topical 1% cyclopentolate on IOLMaster biometry. Optom Vis Sci. 2014;91:1343-7.
5. Özyol P, Özyol E, Baldemir E. Changes in ocular parameters and intraocular lens powers in aging cycloplegic eyes. Am J Ophthalmol. 2017;173:76-83.
6. Cheung SW, Chan R, Cheng R, et al. Effect of cycloplegia on axial length and anterior chamber depth measurements in children. Clin Exp Optom.2009;92:476-81.
7. Higashiyama T, Iwasa M, Ohji M. Changes in the anterior segment after cycloplegia with a biometer using swept-source optical coherence tomography. PLoS One. 2017; 14;12:e0183378.
8. Huang J, McAlinden C, Su B, et al. The effect of cycloplegia on the Lenstar and the IOLMaster biometry. Optom Vis Sci. 2012;89:1691-6.
9. Gürsoy H, Bilge MD, Bilgin M. Okul Çağı Çocuklarında Siklоplejinin Optik Biyometriye Etkisi. Turkiye Klinikleri J Ophthalmol 2016;25:245-50.
10. Raina UK, Gupta SK, Gupta A, et al. Effect of Cycloplegia on Optical Biometry in Pediatric Eyes. J Pediatr Ophthalmol Strabismus. 2018;1;55:260-5.
11. Zocher MT, Rozema JJ, Oertel N, et al. Biometry and visual function of a healthy cohort in Leipzig, Germany. BMC Ophthalmol. 2016; 7;16:79
12. Sampathkumar S, Fan S, Morris N, et al. Aqueous humour dynamics and biometrics in the ageing Chinese eye. Br J Ophthalmol. 2017;101:1290-6.
13. Koç M, Tekin K, Özçelik D, et al. The Effect of Topical Cyclopentolate on Anterior Segment Biometry. Journal of Glaucoma - Cataract 2017:12;1.
14. Olsen T, Corydon L, Gimbel H. Intraocular lens power calculation with an improved anterior chamber depth prediction algorithm. J Cataract Refract Surg. 1995 ;21:313-9.
15. Rodriguez-Raton A, Jimenez-Alvarez M, Arteche-Limousin L, et al. Effect of pupil dilation on biometry measurements with partial coherence interferometry and its effect on IOL power formula calculation. Eur J Ophthalmol. 2015;25:309-14.
16. Khambhiphant B, Chatbunchachai N, Pongpirul K. The effect of pupillary dilatation on IOL power measurement by using the IOLMaster.Int Ophthalmol. 2015;35:853-9.
17. Arriola-Villalobos P, Díaz-Valle D, Garzòn N, et al. Effect of pharmacologic pupil dilation on OLCR optical biometry measurements for IOL predictions. Eur J Ophthalmol. 2014;24:53-7.
18. Arriola-Villalobos P, Almendral-Gómez J, Garzón N, et al. Effect of pharmacological pupil dilation on measurements and iol power calculation made using the new swept-source optical coherence tomography-based optical biometer.J Fr Ophtalmol. 2016;39:859-65.

19. Khambhiphant B, Sasiwilasagorn S, Chatbunchachai N, et al. Effect of pupillary dilation on Haigis formula-calculated intraocular lens power measurement by using optical biometry.Clin Ophthalmol. 2016; 27;10:1405-10.

20. Teshigawara T, Meguro A, Mizuki N. Influence of pupil dilation on predicted postoperative refraction and recommended IOL to obtain target postoperative refraction calculated by using third- and fourth-generation calculation formulas.Clin Ophthalmol. 2018; 2;12:1913-19.

21. Heatley CJ, Whitefield LA, Hugkulstone CE. Effect of pupil dilation on the accuracy of the IOLMaster. J Cataract Refract Surg. 2002 ;28:1993-6.

22. Chang SW, Lo AY, Su PF. Anterior segment biometry changes with cycloplegia in myopic adults. Optom Vis Sci. 2016;93:12-8.

23. Cheng HC, Hsieh YT. Short-term refractive change and ocular parameter changes after cycloplegia. Optom Vis Sci. 2014;91:1113-7.

24. Zhao J, Chen Z, Zhou Z, et al. Evaluation of the repeatability of the Lenstar and comparison with two other non-contact biometric devices in myopes. Clin Exp Optom. 2013;96:92-9.

25. Manny RE, Fern KD, Zervas HJ, et al. 1 % Cyclopentolate hydrochloride: another look at the time course of cycloplegia using an objective measure of the accommodative response. Optom Vis Sci. 1993 ;70:651-65.