Comparison of Cyclopentolate Versus Tropicamide Cycloplegia in Children

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ABSTRACT
This double masked study compares the cycloplegic effects of tropicamide 1% and cyclopentolate 1% in 20 nonstrabismic, nonamblyopic, hyperopic 6- to 12-year-old children with a mean refractive error = +1.48 ± 1.10 diopters (D). Unlike previous studies which used only amplitude of accommodation to measure the depth of cycloplegia, this study compares refractive error as determined by retinoscopy, distance subjective refraction, and distance autorefraction (Canon R-1). In addition, we compare the amplitude of accommodation as measured by subjective push-up and objective autorefraction methods. There is no statistically significant difference between cyclopentolate and tropicamide for either cycloplegic retinoscopy or distance subjective refraction. Autorefraction measurement of refractive error shows a statistically significant but clinically unimportant bias (0.14 ± 0.30 D) toward more hyperopia with cyclopentolate. Both drops reveal latent hyperopia, and the mean latencies are not statistically different between the two cycloplegic agents. Latent hyperopia is not systematically related to the degree of hyperopia after tropicamide, but this relation is significant after cyclopentolate. No differences were found between autorefractive results with either agent at 30 min compared to 60 min after drop instillation. When measured objectively with the autorefractor, accommodation is inhibited more effectively by cyclopentolate than by tropicamide. Our results suggest that although tropicamide is not as effective as cyclopentolate in inhibiting accommodation, it is, nevertheless, a useful cycloplegic agent for measuring distance refractive error of low to moderate hyperopia in school-aged children.

Key Words: cyclopentolate, cycloplegia, hyperopia, refraction, tropicamide

Eye care practitioners frequently perform cycloplegic refractions on children. A cycloplegic agent limits or inhibits accommodation in order to determine the "latent" refractive error, i.e., the amount of hyperopia ordinarily masked by accommodation when viewing a distant target. Cycloplegic agents are useful for revealing more of the latent hyperopia in cases of accommodative esotropia, hyperopic amblyopia, or asthenopia. However, an eye care practitioner often performs a routine cycloplegic refraction on a school-aged child who does not have strabismus or amblyopia in order to measure the amount of latent hyperopia. Cycloplegia is also a consideration in the conduct of large-scale studies of refractive error.6,7 The Orinda Longitudinal Study of Myopia is a 7-year investigation of refractive error development and normal eye growth in schoolchildren, 6 to 14 years old. Because we were concerned about the side effects of cyclopentolate in this community-based study, we used tropicamide as our cycloplegic agent. We therefore wanted to evaluate the efficacy of tropicamide as a cycloplegic for such large-scale studies as well as for general clinical use.

Cyclopentolate is generally accepted as a topical agent which produces excellent cycloplegia, with residual accommodation estimates between 1.00 and 2.50 D as shown by push-up amplitude.3-8 The drug is also associated with central nervous system side effects such as cerebellar dysfunction, visual and tactile hallucinations, drowsiness, ataxia, disorientation, incoherent speech, restlessness, and emotional disturbances.3-15 These effects, along with milder episodes of disorientation and confusion, have occurred after application of cyclopentolate 2% in as many as 24% of children,11 and in 4% of children receiving only 0.5% or 1% concentrations.14 Dizziness, nausea, or mood changes have been reported in 15% of adults receiving cyclopentolate 2%. Tropicamide, on the other hand, is associated with a very low incidence of systemic toxicity. Yolton et al. reported no adverse systemic effects for tropicamide in a review of 15,000 diagnostic pharmaceutical applications.16 Garston reported no adverse experiences in over 10,000 applications of tropicamide 1%.17

Although widely used as an effective mydriatic agent, tropicamide’s effectiveness as a cycloplegic agent has been regarded as equivocal. Milder reported average residual accommodation levels of 6.25 D in children up to 9 years old and 3.65 D in

Received January 20, 1993; revision received June 24, 1993.
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children 10 to 14 years old after instillation of 2 drops of tropicamide 1%. Gettes found 60% of patients between 14 and 35 years old had residual accommodation ≥3.50 D 30 min after instillation of 1 drop of tropicamide 1%. Those residual levels decreased when two drops were instilled. More recently, Lovasik has reported residual accommodation of 2.00 D to 4.00 D 20 min after instillation of 1 drop of tropicamide 1% and 1.00 to 2.00 D 20 min after instillation of 1 drop of cyclopentolate 1%. Tropicamide produces a much shorter duration of cycloplegia compared to cyclopentolate. Merrill et al. and Pollack et al. found that tropicamide had its peak effectivity at 30 min and that most of the cycloplegic effects were gone within 2 h. Cyclopentolate is reported to have its peak effectivity from 30 to 60 min after instillation with some cycloplegic effect lasting up to 24 h. Lovasik found that accommodative amplitude was still reduced by 20 to 30% even 7 h after cyclopentolate 1%, whereas 90% of accommodative amplitude was recovered in 4 to 5 h after tropicamide 1%. Others reported cycloplegic effects of cyclopentolate 1% reaching a peak at 30 to 40 min and lasting up to 24 h, and mydriatic effects lasting up to 72 h. Gettes and Belmont found comparable levels of cycloplegia for the two agents, but noted that the effects of tropicamide dissipated more quickly, in 2 to 6 h compared to 6 to 24 h for cyclopentolate. Conversely, Merrill et al. observed that the maximum cycloplegic effect of a single drop of tropicamide 1% at 30 min was greater than that obtained from cyclopentolate 1% or homatropine 1%, but also found that tropicamide cycloplegia was of much shorter duration.

Results similar to those of Merrill et al. can also be found in the non-English literature. Corrêa reported equal reductions in accommodation after tropicamide 0.5% compared to cyclopentolate, although the effects of tropicamide began to dissipate in 30 min rather than 2 h for cyclopentolate. Steiner found these briefer periods of nearly equal residual accommodation when tropicamide 0.5% was compared to homatropine and atropine; also Salvi and Lepri when tropicamide 0.5% was compared to cyclopentolate and homatropine.

Levels of residual accommodation in the studies cited above were all measured subjectively using the push-up amplitude of accommodation method. Recent results from Manny and co-workers have suggested that subjective methods of measuring residual accommodation may underestimate the depth of cyclopentolate cycloplegia when compared to an objective method. This parallels an earlier finding where the mean push-up amplitude of accommodation was 1.42 D in 100 pre-presbyopic subjects 1 h after application of a gel wafer containing 1/50 grain each of homatropine and cocaine, but only 0.043 D when measured objectively. This implies that the subjective, push-up estimates of accommodation remaining after cyclopentolate, and possibly after tropicamide cycloplegia as well, may be too high. Although many studies have compared residual accommodative amplitude between the two cycloplegics, we are not aware of any previous studies which have assessed efficacy by directly comparing refractive results obtained with tropicamide vs. cyclopentolate. Such studies have been performed comparing atropine and homatropine, atropine and cyclopentolate, tropicamide 0.5% and atropine, tropicamide 0.5% and scopolamine, and tropicamide (0.5% and 1%), homatropine, and atropine. This study compares the cycloplegic effect of tropicamide 1% and cyclopentolate 1% in children using distance refractive error as measured by retinoscopy, subjective refraction, and autorefraction. In addition, we compared the two agents by measuring residual accommodation both subjectively, as in past studies, as well as objectively.

**METHODS**

Twenty subjects, 10 girls and 10 boys, ages 6 to 12 years (mean age = 8.8 ± 2.0 years) participated in the study, following appropriate informed consent procedures administered to the children and their parents. Of the 20 subjects, 16 were White (80%), 2 subjects were Black (10%), 1 subject was Hispanic (5%), and 1 subject was Asian (5%). Their cycloplegic refractive errors ranged from +0.25 to +4.50 D, with a mean refractive sphere (±SD) of +1.48 ± 1.10 D by Canon R-1 autorefraction. All subjects had normal ocular health with no strabismus or amblyopia and were able to respond to a subjective refraction.

We tested each subject twice, once with tropicamide 1% (Mydriacyl—Alcon, Fort Worth, TX) and once with cyclopentolate 1% (Cyclogyl—Alcon, Fort Worth, TX). The average time elapsing between testing sessions was 19 days with a range of 4 to 87 days. On both visits only the right eye was cyclopleged and tested. The study was conducted using a double masked design; one investigator who was not involved in the direct measurements randomly selected either tropicamide or cyclopentolate as the drop to be instilled at the first visit. The cycloplegic agent which was not administered at the first visit was then given at the second visit. Neither the investigator making the measurements, the children being tested, nor their parents knew which drop had been instilled.

**Noncycloplegic Measures**

Before any drops were administered, we measured distance visual acuity, followed by retinoscopy, monocular subjective refraction, subjective push-up amplitude of accommodation, autorefraction, and objective accommodative response as measured by autorefraction. Each type of measurement was performed by the same investigator throughout the course of the study. A phoropter was used for retinoscopy and subjective refraction. We performed the subjective refraction by adding plus lenses in 0.25 D steps to the retinoscopy results until the
subject reported that he or she could not identify the letters on the 6/12 (20/40) line of the Snellen acuity chart. We then added $-1.25$ D to the right lens bank of the phoropter and used a Jackson cross-cylinder to refine the cylindrical component of the refractive error. The spherical component was then adjusted to an endpoint of most plus for maximum visual acuity.

We assessed the monocular push-up amplitude of accommodation with the subjective refraction result in place. The subjects reported when a line of 8 point letters became blurry as it was brought toward them on a nearpoint rod. Because the subjects’ amplitude of accommodation was too great, making it difficult for the target to be brought close enough, $5.00$ D was subtracted from the lenses in the phoropter. We then added the power of this auxiliary lens to the dioptic measurement from the nearpoint rod, giving the total push-up amplitude of accommodation.

In order to measure refractive error objectively, we used a Canon R-1 autorefractor. A $+6.50$ D Badal lens system was used to place a target at the subject’s far point (Fig. 1). We instructed the subject to fixate the center of the target, which was then moved away from the subject in order to relax accommodation. The far point was found subjectively as the target position where any further movement away from the subject resulted in blur. Ten consecutive measurements were averaged and corrected for the autorefractor’s calibration to determine refractive error.34

We also used the autorefractor and the Badal lens system to measure accommodative response objectively. The target was moved forward from the subject’s far point to provide $2.00$, $4.00$, and $6.00$ D stimuli to accommodation. At each stimulus level, five autorefraction readings were taken and spherical components averaged to determine the accommodative response.

**Drop Instillation**

After taking noncycloplegic measurements, we instilled 1 drop of proparacaine $0.5\%$ (Spectrum Scientific, Rancho Cucamonga, CA) into the subject’s right eye followed by 2 drops of the chosen cycloplegic agent administered 5 min apart. Proparacaine was used for the subject’s comfort, to decrease reflex lacrimation, and to increase corneal penetration of the cycloplegic agent.35,36 After each cycloplegic drop we asked the subject to close his or her eyes for 30 s in order to minimize discomfort as well as systemic absorption.

**Cycloplegic Measures**

At each visit we tested the subjects at 30 and 60 min corresponding to the reported times of the peak cycloplegic action of tropicamide and cyclopentolate, respectively.5,30,32,35 At 30 and 60 min after the first drop was instilled, visual acuity, retinoscopy, monocular subjective refraction, and subjective push-up amplitude of accommodation were measured, followed by distance autorefration and objective measurement of accommodative response as described above. The subjective refractive correction was increased by $+2.00$ D during push-up amplitude of accommodation measurement under cycloplegia. The $2.00$ D was then subtracted from the dioptic distance on the nearpoint rod, giving the total push-up amplitude of accommodation.

**Parent Observations**

At the end of each testing session, a questionnaire was given to the parent of each subject to be completed at home and returned. The questionnaire requested parents’ observations of the duration of pupillary dilation for the drop received, as well as a report of any side effects noticed by the child or the parent.

**RESULTS**

**Refraction**

Table 1 shows retinoscopy, subjective refraction, and autorefration results for all 20 subjects before drop instillation (noncycloplegic) and for each drug at the generally accepted time of peak cycloplegia (tropicamide at 30 min and cyclopentolate at 60 min). We evaluated the refractive data using only the spherical component of the refractive error as expressed in minus cylinder form. We found that comparison of the cylindrical component obtained by autorefration for each individual subject (mean ± SD for tropicamide at 30 min = $-0.77 \pm 0.93$ D and for cyclopentolate at 60 min = $-0.69 \pm 0.82$ D) showed that this measurement did not vary significantly throughout the study (Student’s paired t-test; $p = 0.22$).

Although retinoscopy revealed more plus than either subjective refraction ($+0.15$ D, $p < 0.005$) or autorefration ($+0.29$ D, $p < 0.001$) when no cycloplegia was used, all three methods yielded similar results when either cycloplegic agent was used (Student’s paired t-test; $p = 0.24$). Autorefration and subjective refraction were not statistically different under any of the three conditions (Student’s paired
TABLE 1. Refractive data. The spherical component of the refractive error by subject obtained using no cycloplegia, tropicamide 1% at 30 min, and cyclopentolate 1% at 60 min measured in dipters.

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Retinoscopy (D)</th>
<th>Subjective (D)</th>
<th>Autorefraction (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noncycloplegic</td>
<td>Tropicamide</td>
<td>Cyclopentolate</td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td>2.25</td>
<td>2.75</td>
</tr>
<tr>
<td>2</td>
<td>2.25</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.00</td>
<td>1.25</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>5</td>
<td>0.88</td>
<td>2.00</td>
<td>2.50</td>
</tr>
<tr>
<td>6</td>
<td>3.75</td>
<td>4.50</td>
<td>4.00</td>
</tr>
<tr>
<td>7</td>
<td>0.75</td>
<td>1.50</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>1.00</td>
<td>1.50</td>
</tr>
<tr>
<td>9</td>
<td>1.88</td>
<td>2.00</td>
<td>2.25</td>
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<tr>
<td>10</td>
<td>0.85</td>
<td>1.00</td>
<td>1.25</td>
</tr>
<tr>
<td>11</td>
<td>0.50</td>
<td>1.50</td>
<td>2.00</td>
</tr>
<tr>
<td>12</td>
<td>0.50</td>
<td>0.25</td>
<td>0.50</td>
</tr>
<tr>
<td>13</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>14</td>
<td>0.50</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>15</td>
<td>0.38</td>
<td>1.00</td>
<td>0.75</td>
</tr>
<tr>
<td>16</td>
<td>0.00</td>
<td>0.50</td>
<td>0.25</td>
</tr>
<tr>
<td>17</td>
<td>0.38</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>18</td>
<td>1.13</td>
<td>1.75</td>
<td>1.75</td>
</tr>
<tr>
<td>19</td>
<td>1.38</td>
<td>2.75</td>
<td>2.75</td>
</tr>
<tr>
<td>20</td>
<td>0.63</td>
<td>0.75</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Mean ± SD: +1.00 ± 0.97 +1.50 ± 1.06 +1.61 ± 1.00 +0.85 ± 0.98 +1.48 ± 1.08 +1.54 ± 0.98 +0.71 ± 0.92 +1.48 ± 1.01 +1.62 ± 1.01

In light of these data and because autorefraction is the most objective and repeatable method of the three, autorefraction measurements were used to analyze the time of peak cycloplegic effect and the latent component of refractive error.

Although the literature indicates that the peak cycloplegic effects of tropicamide and cyclopentolate are at 30 and 60 min, respectively, Student's paired t-test analysis suggests that for either drug the time of testing did not significantly alter the mean autorefraction results (Table 2). Similarly, differences between refractive results at 30 and 60 min were not significantly different for subjective refraction with tropicamide (0.10 ± 0.29 D) or cyclopentolate (0.05 ± 0.30 D), nor for retinoscopy with tropicamide (0.03 ± 0.32 D) or cyclopentolate (0.04 ± 0.30 D; Student's paired t-test, p > 0.13).

Fig. 2(a) is a plot of the differences between the spherical component of the retinoscopic findings using tropicamide 1% and cyclopentolate 1% vs. the mean of these findings. The mean difference between cycloplegic measures is evaluated compared to zero for bias, and 95% limits of agreement between the two methods are constructed (mean ± 1.96 × SD of the differences). This figure shows the difference between retinoscopy results measured with the two agents (cyclopentolate minus tropicamide) vs. the magnitude of refractive error (average of cyclopentolate and tropicamide measurements). Points above the dotted zero line represent subjects for whom cyclopentolate revealed a more hyperopic refractive error, whereas points below the dotted zero line represent subjects for whom tropicamide indicated a more hyperopic refractive error. The mean difference between the two drops was slightly biased toward cyclopentolate (mean = 0.11 ± 0.32 D), as represented by the solid line. We found that this difference was not statistically significantly different from zero (Student's t-test, p = 0.13). The gray shaded area represents the 95% limits of agreement (−0.52 to +0.74 D). The difference in retinoscopy results between the two agents did not exceed 0.50 D for any subject.

Table 2. Time comparison of mean autorefraction results. Mean ± SD of the spherical component of the refractive error as measured by autorefraction at 30 and 60 min after instillation of the first of 2 drops tropicamide 1% and cyclopentolate 1%. No differences between the two times are statistically significant.

<table>
<thead>
<tr>
<th>Time of Testing</th>
<th>Tropicamide Mean ± SD (D)</th>
<th>Cyclopentolate Mean ± SD (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min</td>
<td>+1.48 ± 1.01</td>
<td>+1.62 ± 1.01</td>
</tr>
<tr>
<td>60 min</td>
<td>+1.44 ± 0.96</td>
<td>+1.62 ± 1.01</td>
</tr>
<tr>
<td>p value</td>
<td>p = 0.40</td>
<td>p = 0.98</td>
</tr>
</tbody>
</table>

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Figure 2. Difference vs. mean graphs for retinoscopy, subjective refraction, and autorefraction. The x axis is the average sphere of the cyclopentolate and tropicamide refractive measurements. The y axis is the cyclopentolate sphere minus the tropicamide spherical measurement. Points above the dotted line represent subjects for whom cyclopentolate produced a more hyperopic refractive error, whereas points below the dotted line represent subjects for whom tropicamide produced a more hyperopic refractive error. The solid line represents the mean difference between the two drops for all subjects. For (a) and (b) there is no statistically significant bias for either tropicamide 1% or cyclopentolate 1%. Only in (c) (autorefraction) is the mean difference statistically significant biased toward cyclopentolate. The gray shaded area represents the 95% limits of agreement between tropicamide and cyclopentolate for each refraction method.

amount of latent hyperopia compared to noncycloplegic autorefraction. With tropicamide the average latency for all subjects at 30 min is 0.77 ± 0.45 D (Student’s paired t-test, p < 0.0001), whereas for cyclopentolate the average latency obtained is slightly higher at 0.91 ± 0.57 D (Student’s paired t-test, p < 0.0001). However, this difference in latency between the two drops is not statistically significant (Student’s paired t-test, p = 0.18). Although the latency is not related systematically to the amount of hyperopia with tropicamide (r = 0.34, p = 0.14), there is a significant relation between these two variables for cyclopentolate (r = 0.45, p = 0.045).

Accommodation

The mean accommodative response to 2.00, 4.00, and 6.00 D targets as objectively measured by autorefraction is shown in Table 4. Values shown are for tropicamide at 30 min and for cyclopentolate at 60 min. For each stimulus level, cyclopentolate more strongly suppresses the accommodative response to a statistically significant extent (Student’s paired t-test, p < 0.013). This difference in residual accommodation does not achieve significance when measured subjectively (Table 4; Student’s paired t-test, p = 0.08). Comparison of residual accommodation as measured by subjective push-up and objective autorefraction methods shows the large discrepancy between the results obtained by the two methods. The mean residual accommodation for tropicamide determined subjectively was 3.27 D as compared to the objective method’s result of 0.71 D for the 6.00 D accommodative stimulus. Similarly, for cyclopentolate the subjective method measured a mean of 2.60 D of residual accommodation, whereas the objective method found a mean of 0.24 D. Precycloplegic measures of accommodative response are also shown in Table 4. Subjects display lag of accommodation at each stimulus level, but a reasonably linear response to the accommodative target. The lower levels of residual accommodation measured by the objective method are therefore not likely to occur because the target depicted in Fig. 1 is an ineffective stimulus to accommodation.

Parent Observations

The parents of 17 of the 20 subjects completed and returned questionnaires for the sessions in which we administered tropicamide. The parents reported a duration of dilation ranging from 3 to 24 h. In most cases test sessions were conducted in the early evening, and the most common estimate of tropicamide dilation duration was “Gone by morning.” Sixteen of the 20 questionnaires were returned for the cyclopentolate sessions, reporting a duration range of 24 to 72 h, with the most common response being “Two days.”

DISCUSSION

Comparison of refractive results between tropicamide and agents other than cyclopentolate, although reported in journals generally inaccessible to the English-speaking clinical community, are consistent with the results reported here. Steusloff
Table 3. Comparison of average refractive error—tropicamide vs. cyclopentolate. Mean ± SD of the spherical component of the refractive error as measured by the methods used in this study 30 min after tropicamide 1% and 60 min after cyclopentolate 1%. The difference between the two drops as measured by autorefractometry is statistically significant.

<table>
<thead>
<tr>
<th>Refraction Method</th>
<th>Tropicamide at 30 min Mean ± SD (D)</th>
<th>Cyclopentolate at 60 min Mean ± SD (D)</th>
<th>Cyclopentolate-Tropicamide: Mean Difference ± SD (D)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retinoscopy</td>
<td>+1.50 ± 1.06</td>
<td>+1.61 ± 1.00</td>
<td>-0.11 ± 0.32</td>
<td>p = 0.13</td>
</tr>
<tr>
<td>Subjective</td>
<td>+1.48 ± 1.08</td>
<td>+1.54 ± 0.98</td>
<td>-0.06 ± 0.34</td>
<td>p = 0.42</td>
</tr>
<tr>
<td>Autorefractometry</td>
<td>+1.48 ± 1.01</td>
<td>+1.62 ± 1.01</td>
<td>-0.14 ± 0.30</td>
<td>p = 0.045*</td>
</tr>
</tbody>
</table>

* Statistically significant.

Table 4. Comparison of residual accommodation before and after cycloplegia. Accommodative response was measured by autorefractometry at stimulus levels of 2.00, 4.00, and 6.00 D, whereas the push-up method assessed the maximum subjective amplitude. Measurements were taken for tropicamide at 30 min and cyclopentolate at 60 min. Note that the levels of residual accommodation for both drop types are substantially lower when measured objectively rather than subjectively, and that cyclopentolate inhibits accommodation to a greater degree than tropicamide when measured by autorefractometry.

<table>
<thead>
<tr>
<th>Accommodative Stimulus (D)</th>
<th>Precycloplegic Mean ± SD (D)</th>
<th>Tropicamide at 30 min Mean ± SD (D)</th>
<th>Cyclopentolate at 60 min Mean ± SD (D)</th>
<th>Significance of Difference between Cycloplegics N = 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective autorefractor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>1.11 ± 0.36</td>
<td>0.50 ± 0.50</td>
<td>0.11 ± 0.25</td>
<td>p = 0.002*</td>
</tr>
<tr>
<td>4.00</td>
<td>2.61 ± 0.60</td>
<td>0.67 ± 0.92</td>
<td>0.11 ± 0.53</td>
<td>p = 0.002*</td>
</tr>
<tr>
<td>6.00</td>
<td>4.68 ± 0.76</td>
<td>0.71 ± 1.19</td>
<td>0.24 ± 0.72</td>
<td>p = 0.013*</td>
</tr>
<tr>
<td>Subjective Push-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>11.71 ± 1.61</td>
<td>3.27 ± 1.72</td>
<td>2.60 ± 1.32</td>
<td>p = 0.08</td>
</tr>
</tbody>
</table>

* Statistically significant.

presented the differences between 160 refractions using atropine 1% and those using tropicamide 0.5% in what was apparently a general clinical practice. Although there are no signs given to the differences, even assuming that all the differences are in the direction of more hyperopia with atropine, the mean difference would only be +0.54 ± 0.35 D.31 Bernoulli reported the retinoscopic refractive errors of 20 hyperopic children aged 3 to 16 years, with refractive errors ranging from +0.50 to +7.00 D after tropicamide 0.5% and scopolamine 0.2%. Analysis of his data shows that the average difference in refractive error was +0.24 ± 0.38 D more hyperopia with scopolamine than with tropicamide.32 Wolter-Czerniak et al.33 compared refractive errors in 55 subjects from 4 to 20 years of age, and from +6.20 to −6.50 D in refractive error using atropine 1%, tropicamide 0.5% and 1%, and homatropine 1%. For hyperopes in the youngest age groups, tropicamide 1% resulted in an average refractive error only 0.30 to 0.50 D less hyperopic than that with atropine 1%, and up to 0.30 D more hyperopic than homatropine 1%. Refractions done with tropicamide 1% and 0.5% were within 0.20 D of each other.33 Tropicamide is frequently criticized as a cycloplegic agent based on measures of residual accommodation. However, this criticism appears to be overstated for two reasons: (1) residual accommodation was measured solely by the push-up method, and (2) refractive error was not specifically used to determine the effectiveness of cycloplegia.

We found that subjective push-up measurements greatly overestimated residual accommodation as compared to objective measurement of accommodation using the autorefractor. These findings are in agreement with those of Mandy et al. with cyclopentolate.27 Overestimates of residual accommodation are likely to occur with push-up measures, especially with children, because of the depth of focus but also because of subjective factors such as their questionable judgment of first blur. These factors are eliminated with objective autorefractometric measurement. Thus, studies which criticize the cycloplegic effects of tropicamide based on push-up measurements may underestimate tropicamide’s usefulness.

This does not imply that the two agents provide equivalent cycloplegia. Although residual accommodation for both cycloplegics was much lower when measured objectively, we still found 0.39 to 0.56 D more residual accommodation with tropicamide than with cyclopentolate (Table 4). The difference in latent hyperopia revealed by the two drugs was not significant, but the slightly greater amount produced after instillation of cyclopentolate may explain this difference because the latency of the effect was not significant and the difference between the two agents in latency is far less than implied by past literature.2,4,18,19 Nevertheless, these small differences in the level of cycloplegia may not be relevant to the clinical utility of tropicamide for measurement of distance refractive error. In contrast to previous studies which only considered residual accommodation, we
focused on refractive results because these are, typically, the clinical data which are of most concern to the eye care practitioner. When the cycloplegic effects of tropicamide and cyclopentolate are analyzed using refractive error data, two of the three methods show no differences; there is only a small bias (0.14 D) toward more hyperopia with cyclopentolate using autorefraction. However, we do not consider this difference between the two agents to be clinically meaningful.

Furthermore, determination of refractive error by retinoscopy, subjective refraction, or autorefraction with either tropicamide or cyclopentolate can be accurately performed at either 30 or 60 min after drop instillation. This becomes useful in clinical practice where the method of evaluating refractive error and the flexibility of timing are important considerations.

In addition, tropicamide has advantages over cyclopentolate for the patient, including increased comfort and decreased likelihood of side effects. The informal survey of the subjects’ parents found a much shorter reported duration of pupillary dilation with tropicamide than with cyclopentolate. After testing sessions with tropicamide, parents reported relatively mild side effects including headache, lack of energy, and slight hyperactivity. During a testing session in which cyclopentolate was administered to one child, we observed that he became flushed and drowsy. Parent reports of side effects observed after cyclopentolate use included fatigue, hyperactivity, and visual disturbances. One parent observed that her child “acted jumpy/hyper leaving from one test point to another, seeing her little sister’s face as blue.” Although anecdotal, these observations are in agreement with reports of more significant side effects with cyclopentolate and support the use of tropicamide over cyclopentolate whenever possible.3-16

CONCLUSIONS

Cycloplegic refractions are useful in children because children’s ability to accommodate is greater than that of adults, and children often have difficulty directing their attention to a distant target for any length of time. Our results confirm previous studies3,8,16,19 which found that cyclopentolate inhibits accommodation more effectively than does tropicamide. Nevertheless, the amount of residual accommodation does not necessarily affect distance refractive error, assuming a cooperative and attentive subject.

Our data show that tropicamide is a useful and effective cycloplegic agent with minimal adverse side effects for clinical refraction of nonstrabismic, nonamblyopic, school-aged children at either 30 or 60 min after drop instillation. These attributes may make it preferable to cyclopentolate in research involving large populations of school-aged children in which minimizing side effects and losses to follow-up are important.19 Based on the protocol of this study, when tropicamide is used as a cycloplegic agent, we recommend that 2 drops of tropicamide 1% be administered 5 min apart, preceded by 1 drop of proparacaine 0.5% to decrease stinging from the tropicamide drops.

Further studies are needed to assess tropicamide’s usefulness as a cycloplegic agent in other populations such as infants, high hyperopes, strabismics, and specific ethnic groups.

ACKNOWLEDGMENT

This study was supported by National Institutes of Health/National Eye Institute Grant R01 EY08893 (National Eye Institute, National Institutes of Health, Bethesda, MD).

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