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# The Comparative Efficacy of Cyclopegic Drugs–Tropicamide and Cyclopentolate on School Children

Desmond Eberechukwu Ihekaire[i]
Department of Optometry, Faculty of Health Sciences
Imo State University, Owerri, Nigeria

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Abstract

This study compared the cycloplegic action of equiconcentration of tropicamide and cyclopentolate, as well as effects on visual acuity at far and near, near and far phorias, and amplitude of accommodation. Twenty five ocular healthy persons of both gender between the ages of 17 and 29 were used for this study. The result from this study showed that 1 drop of 1% solution of tropicamide as it reduces the quantity and quality of the variables considered. In each case, exophoria tended toward esophoria or less exophria while exophoria tended to increase. It is concluded that tropicamide though less effective, is a more useful cycloplegic than cyclopentolate because its use is not associated with such time and action inconveniences and complications as observed with cyclopentolate. Based on the above findings and observations, for optimal and complication free diagnostic and therapeutic procedures, the use of tropicamide in an appropriate concentration of 0.5 percent to 1 percent is recommended over the use of cyclopentolate.

Reference to this paper should be made as follows:

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## INTRODUCTION

Through advancement in optometric practice, practitioners have been exposed to the use of therapeutic and diagnostic agents much to the advantage of patients (OPR, 2012). One such advancement is the application of cycloplegic agents to the eyes to either enhance or diminish the functions of the ocular system (Pavan-Langston, 2005). The most desired effect of these cycloplegic agents is their effect on the ciliary muscles of the eyes, which are paralyzed to bring about relaxation or a complete elimination of accommodation, that is, cycloplegia. Cycloplegia is the paralysis of the ciliary muscles achieved by blocking the muscarinic receptors normally stimulated by the release of acetylcholine from the nerve endings of the parasympathetic system. Since the parasympathetic nervous system also enervates the pupil sphincter pupillae muscle, cycloplegia is always accompanied by mydriasis (although mydriasis is not always accompanied by cycloplegia) (Aneja, 2007). Cycloplegic drugs are used to produce the above effects and can thus prevent or reduce accommodation during refraction, thus making latent refractive errors manifest.

A proper and adequate fundoscopic examination is central to accurate diagnosis and treatment in the practice of optometry. A satisfactory prescription for glasses may be given only after the examiner has accurately determined the refractive status of the eye and made allowances for the tonus of the ciliary body or the accommodative power (Beazley et al., 2012).

The punctum remotum, or the far point of the eye, is the conjugate focus of the retina when the eye is in a non-accommodative state. Since the first step with any refractive technique is to determine the far point of the eye, clinical methods to suspend accommodation during the examination are needed (Kaufman, [n.d]; Apt & Gaffney, [n.d]; Banks, 1980). This can be achieved in one of two ways:

1.  by inserting stronger convex or plus lenses than necessary in front of the eye, known as the "fogging technique"; or
2.  by paralyzing the accommodative power of the eye with drugs, the result of which is "cycloplegia."

All topical drugs, when instilled into the conjuctival sac are rapidly absorbed through the cornea and become effective in the inner part of the eye (Urtti, 2006; Jankov et al., 2006). Constriction of the pupil by the third cranial (CNII) is due to the liberation of acetylcholine, which when formed and accomplished, immediately begins to destroy the enzyme cholinesterase. One drug, of which tropicamide and cyclopentolate are prototypes, abolishes the action of acetylcholine and thus causes mydriasis by preventing the sphincter from contraction (parasympatholytic drugs).

The sphincter pupillae and ciliary muscles, which belong to the adrenergic system, are innervated by the postganglionic parasympathetic efferent fibres of the short ciliary nerve branches of the oculomotor nerve (CN III) that have synapsed in ciliary ganglion. The dilator pupillae muscle is innervated by long ciliary nerves carrying postganglionic fibres of the sympathetic nervous system that have synapsed in the superior cervical ganglion. Cholinergic stimulation of the sphincter pupillae muscle causes papillary constriction (miosis), and cholinergic stimulation of the ciliary muscle brings about increased accommodation. Blockade of the cholinergic system dilates the pupil (mydriasis) and relaxes the ciliary muscle, causing a decrease in accommodation (cycloplegia).

Adrenergic stimulation causes papillary dilation, while adrenergic blockade causes papillary constriction. This suggests that the cilliary muscle may have a minor adrenergic innervation, with stimulation decreasing accommodation. In other words, more pronounced cholinergic effects obscure adrenergic effects.

Cholinergic blocking drugs, mainly of the atropine group, interfere with the actions of acetylcholine in nerve transmission at the following sites:

-   The motor endplate of post ganglionic parasympathetic nerve fibres in smooth and cardiac muscles – these structures are stimulated by muscarine and blocked by the atropine group of drugs;
-   The autonomic ganglia of both parasympathetic and sympathetic nervous systems – nicotine in small doses stimulates ganglionic stimulation, with the action being opposed by ganglionic blocking agents; and
-   Both the motor endplate of the skeletal muscle and the central nervous system.

Mydriatics are agents that bring about increase in pupil size and the accommodative convergence accommodation ratio, as well as a decrease in visual acuity and the amplitude of accommodation. A widely dilated pupil is often required in fundoscopic examinations where retinal or lenticular peripheries are to be visualized through microscopy, ophthalmoscopy or fundus photography. In this process, the smooth muscles of the iris are ultimately activated. Mydriasis is thus the result of an imbalance in favour of dilator action which can be caused by:

1.  increased activity along the sympathetic pathway;
2.  decreased activity along the parasympathetic pathway;
3.  direct stimulation or inhibition of the effector smooth muscles
    (Lowenstein & Loewenfeld, 1962).

Two classes of drugs produce a mydriatic effect when instilled into the eye:

1. Sympathomimetic agents, including phenylepherine, hydroxyamphetamine, cocaine, adrenaline, and ephedrine; and
2. Parasympatholytic agents, including atropine, tropicamide, (mydriacyl), and cyclopentolate (cyclogyl).

## CYCLOPLEGIC REFRACTION

### Historical Background

The history of cycloplegic refraction has been reviewed in detail by Bannon. He notes that Piny (23–79 AD) discussed various herbs used to dilate the pupil for the treatment of corneal ulcers, cataracts and other ocular conditions. Throughout the 16th century, atropine and other drugs were used to dilate the pupil for cosmetic purposes (as suggested by the name, belladonna). Atropine's cycloplegic effect however, was not known until 1811 when William Wells, a London oculist, discovered that a patient whose pupils were dilated and had partial ptosis also had a failure of accommodation. It occurred to Wells that this effect might be caused by belladonna, and he convinced a younger physician, Cutting, to allow him to instill belladonna in his left eye. Cutting's accommodation was reduced from about 7.000 to less than 1.000 in about 45 minutes, and his power of accommodation did not return for eight days. His refractive state also changed from slightly myopic to slightly hyperopic (Manny et al., 2001).

As Bannon reflects, it would still be another fifty years before Donders would popularize cycloplegic refraction on scientific grounds. With his 1864 publication of "On the Anomalies of Accommodation and Refraction of the Eye", the use of cycloplegics in refraction became a universally accepted method. Evidence from earlier workers indicated that the orthodox method of refraction in America ophthalmologists entailed the use of cycloplegics. Although, as early as the 1980, Howe in Grosvenor (1989) suggested that while refraction was possible without cycloplegics, ophthalmologic training was (and, to a great extent, still is) carried out in hospitals and clinics where patients were often children, illiterate adults or the elderly whose resistance made the use of cycloplegic refraction methods difficult.

### Cycloplegic Agents

Cycloplegic agents are drugs that act by antagonizing the muscarinic action of acetylcholine. They do so by blocking its action at structures innervated by postganglionic parasympathetic nerve fibres. These agents paralyse the constrictor pupillae as well as the ciliary muscle, causing mydriasis as well as cycloplegia.

For many years, atropine was the only cycloplegic agent available. To bring about full cycloplegia in children, it had to be instilled two or three times daily for three days prior to cycloplegic refraction. The resulting cycloplegia persisted for seven to ten days and the accompanying mydriasis lasted as long as two weeks.

Homatropine is a semi-synthetic alkaloid. It is not, however, considered to produce sufficient cycloplegia in children under the age of 15. Although compared with atropine, only a few drops are required, and the cycloplegic effect begins in a matter of 45-60 minutes, due to the availability of newer preparations, homatropine is not frequently used today.

Cyclopentolate (cyclogyl) is a short acting cycloplegic agent available in 0.5 and 1.0 percent solutions. With this agent, cycloplegia occurs within 30-45 minutes and persists for up to 24 hours. Even though it does not yield as complete cycloplegia in children as atropine does, Davies (1989) considers it to be a suitable alternative to atropine for children, even under the age of six if one or two drops of one percent solution are administered. For adults, he recommends one drop of 0.5 percent solution.

Reports of central nervous system effects following the use of cyclopentolate include confusion, ataxia and personality changes. Lyle and Hopkins (1977) reported that in almost all of these cases, the effect accompanied higher than recommended dosage or the combination of cyclopentolate and other muscarinic agents.

Tropicamide (Mydriacy I) is also a short acting cycloplegia available in 0.5 and 1.0 percent solutions. For young adults, three or four drops of the 1.0 percent solution, separated by a few minutes, will bring about full cycloplegia, and recovery occurs in two to six hours. Davies (1989) considers tropicamide inadequate for producing cycloplegia in children. According to Lyle and Hopkins (1977), reports of adverse reactions to tropicamide are made conspicuous by their rarity. In addition to its use as a cycloplegic, tropicamide is widely used as a mydriatic agent.

### Choice of a Cycloplegic Agent

There appears to be little doubt that in children below the age of six years, complete cycloplegia can be obtained only with the use of atropine. However, the use of atropine is attended by a number of complications and dangers:

1. Parents must co-operate by instilling the ointment in the child's eye twice per day for 3 days;

2. The resulting cycloplegia may last as long as two weeks;

3. The ointment is poisonous and can cause death if taken by mouth, and

4. For a child with intermittent convergence strabismus or high eusophoria, there is a possibility that complete cycloplegia can cause a constant convergent strabismus (Davies, 1989).

Despite its effectiveness, because of these problems the optometrist should consider the use of a less potent cycloplegic agent, such as cyclopentolate or tropicamide. If the cycloplegic refraction is needed to uncover latent hyperopia that may be responsible for a child's convergent strabismus, the fact that a full cycloplegic effect will not occur is of no great consequence.

When an agent other than atropine is used for cycloplegic refraction, it is not considered necessary to subtract a "tonus allowance" as it is when atropine is used. However, in some cases, the prescription of the full plus found in cycloplegic refracting may result in complaints of blurred distance vision. On the basis of Davies (1989) report, that twenty patients between the ages of 10 and 14 who were refracted under tropicamide had an average amount of residual accommodation of 3.56D, it is recommended that cyclopentolate (1 percent) be used for children. Tropicamide, however, will induce an adequate cycloplegic effect in adults.

**Indication for Cycloplegic Refraction**

Of the three major classes of diagnostic pharmaceutical agents that optometrists use, cycloplegic agents are indicated in far fewer cases than either mydriatic agents or anesthetics. Mydriatics are used frequently by practitioners who use binocular indirect ophthalmoscopy and fundus photography, while topical anesthetics are used routinely by practitioners who perform applanation tonometry and gonioscopy. Cycloplegic refraction is in fact necessary for only a small percentage of patients.

**Children**

When a child (often a pre-scholar) is seen with a convergent strabismus, the practitioner must determine whether there is an accommodative element in the strabismus. The only way to do this is through cycloplegic refraction. If cycloplegic refraction yields little or no uncorrected hyperopia, the condition is not accommodative strabismus, and the prognosis for non-surgical cure may be unfavourable. However, if several diopters of uncorrected hyperopia are found, the strabismus is accommodative, and a full correction for the hyperopia (possibly with an addition for near work) will greatly reduce or completely eliminate the esotropia.

The use of cycloplegic refraction should also be considered for a child whose eyes are normally straight but who has significant amount of esophoria (a deviation occurring only when fusion has been interrupted), particularly if the esophoria is present at the 40cm distance. Because the combination of hyperopia and esophoria in near work is often responsible for asthenopic symptoms and a distaste for reading, any latent hyperopia found through cycloplegic refraction should be corrected. As noted earlier, tropicamide causes insufficient relaxation of accommodation in children, so cyclopentolate (1 per cent) should be used to make such determinations.

**Young Adults**

For young adults between the ages of 16 and 40, latent hyperopia is sometimes a problem. Its presence should be suspected whenever a patient complains of headaches or other symptoms associated with near work but has little or no uncorrected hyperopia and no other refractive or binocular vision anomaly. The use of overfogging procedures, such as Borish's delayed subjective can, in many cases, make procedures fail to uncover the expected latent hyperopia. Tropicamide (1 percent) is considered to be the best cycloplegic agent because it has virtually no side effects. However, it is necessary to use 3 to 4 drops of 1 percent tropicamide to produce a cyclolegic effect similar to that brought about by one drop of 1 percent cyclopentolate.

**Older Adults**

The need for cycloplegic refraction falls markedly with age. Beyond the age of 40, the amplitude of accommodation decreases rapidly and is essentially non existent by the age of 55. Consequently, patients over the age of 40 would not be expected to have latent hyperopia that went undetected in routine fogging procedures.

**Statement of the Problem**

In the practice of optometry, there are cases where ophthalmoscopy and refraction can be difficult due to congenital myopic pupil, crystalline lens opacity. Refraction also proves difficult in children of preschool age, illiterates, the intellectually challenged, persons experiencing language barriers, and in those with ciliary spasms.

After the completion of refraction by some subjective technique, examination either discloses a receding near point accommodation or the punctum remotum is quite remote for the individual's age thus indicating a hypertonicity of ciliary muscles. In such cases, the optometrist immediately begins to think about relaxing or paralyzing accommodation and dilating the pupil with a cycloplegic agent. The choice of the cycloplegic agent is dictated by the onset of action and the desire for a quick recovery with minimal side effects in order not to inconvenience the patient.

Since both cyclopentolate and tropicamide are effective cycloplegic agents, the question becomes which of the two better meets the above requirements for an effective clinical procedure involved in the day-to-day practice of optometry. This question may be answered if the following sub-questions (research questions) can be addressed:

1. Does the onset of action of tropicamide differ from that of cyclopentolate?
2. Does the duration of action of tropicamide differ from that of cyclopentolate?
3. Does the rate of papillary dilatation with tropicamide differ from that of cyclopentolate?
4. Does the loss in amplitude of accommodation with tropicamide differ from that of cyclopentolate?
5. Is there any difference in the mean time needed to achieve peak mydriasis with tropicamide and cyclopentolate?
6. If there any difference between the onset of recovery of accommodation with tropicamide and cyclopentolate?
7. Is there any difference between the cycloplegic properties of tropicamide and those of cyclopentolate?

**Objective of the Study**

This study aims to complete the cycloplegic effect of tropicamide and that of cyclopentolate among young adults. This will be achieved by:

1. Comparing the onset of action of tropicamide and cyclopentolate;
2. Comparing the time of peak mydriasis of the two drugs;
3. Comparing their duration of action;
4. Comparing the recovery rate of accommodation with both tropicamide and cyclopentolate.

Previous research has confirmed that tropicamide and cyclopentolate are the most suitable alternatives to atropine as far as cycloplegia is concerned (although they do not achieve as complete cycloplegia as atropine does), especially in children between the ages of 6 and 16 years old. At the same time, some consideration has been given to clarifying what constitutes adequate and effective cycloplegia. Gettes (1961) asserts that there must be less that 2.50D residual accommodation at the time of retinoscopy and examination for a cycloplegic agent to be effective. This will be taken as a baseline for this study.

**Significance of the Study**

Health care practices, including optometry are continuously growing and expanding their understanding of human health and afflictions. The importance of research into the diagnostic and therapeutic aspects of optometry thus cannot be over emphasized with respect to the maintenance of effective and convenient optometry practices. Given that the eye is the most precious human sense organ, caution must be exercised in choosing drugs to be used in clinical diagnostic examinations. Generally optometry drugs are chosen for convenience of application, desired effect in the least possible time, quickest recovery rate and minimal adverse effects. In this study, the cycloplegic effect of tropicamide is compared with that of cyclopentolate in meeting these requirements. This study also looks at the lowest possible percentage concentrations needed for effective therapeutic diagnoses and treatment. This research will thus also help to determine the minimum number of drops required for effective cycloplegia, thereby reducing the risk of over dosage.

This study will undoubtedly compliment the scope and context of hitherto existing literature on cycloplegics, especially research on cyclopentolate and tropicamide. For those already in or just entering the eye care profession, this study may expose certain hidden properties of these drugs which will in turn precipitate further studies.

## REVIEW OF RELATED LITERATURE

In order to ensure a proper understanding of cycloplegia, it is important to offer some knowledge of the anatomy of the sphincter pupillae and dilator pupillae muscles of the iris and ciliary body.

The automatic nervous system can be divided into parasympathetic (or cholinergic) and sympathetic (or adrenagic) systems. Drugs affecting these systems may in turn be divided into cholinergic stimulating (agonist) and cholinergic blocking (antagonist) agents. Acetylcholine is the cholinergic neurohumoral transmitter and norepinephrine (noradrenaline, levarterenol) is the main adrenergic neural transmitter. Acetylcholine is inactivated by the enzyme cholinesterase, whereas norepinephrine is largely inactivated (90 percent) through re-uptake by the axon that released it or by enzyme catechol-0-methyl transferase. The amount of norepinephrine stored in the axon of the synaptic junction is limited by the inactivation of norepinephrine by monoamine oxidase.

### Cycloplegics

Cycloplegics are chemical agents (drugs) that paralyze the ciliary muscles by blocking the muscarinic receptors that are normally stimulated by the release of acetylcholine from the nerve endings of the parasympathetic system. Cycloplegia is always accompanied by mydriasis since the pupil sphincter pupillae muscle is inervated by the parasympathetic nervous system. However, mydriasis is not always accompanied by cycloplegia. Although there are a number of these cycloplegic agents, this literature review will focus on tropicamide and cyclopentolate.

### Mydriatics and Mechanism of Action

Physiologically, the pupil size is about 3mm – 4mm, but this is not universal. Myopes, for instance, are credited with large pupils, and hyperopes, astigmats, and emmetropes are known to have smaller pupils (Borish, 1970). Mydriasis can be achieved by using one of three types of pharmacological agents:

- Sympathomimetic agents, including phenylepherine, adrenaline, and cocaine;
- Parasympatholytic agents, including tropicamide, cyclopentolate, and atropine; and
- Ganglionic blocking agents, including hexamithonium.

These agents produce mydriasis through the:

1. Blockade of normal sphincter tone by inhibiting the action of acetylcholine, as liberated by postganglionic parasympathetic nerves (the muscarine blocking drugs). The ciliary muscle is likewise affected by the same type of innervation. In order to obtain a selective mydriasis, therefore, it is pertinent to choose drugs with lower potency than atropine or to use lower concentrations of the cycloplegic agents.
2. Stimulation of the dilator pupillae muscle which will bring about a selective mydriasis. Drugs that act in this way mimic the action of nor-adrenaline liberated from the post-sympathetic nerve, and are, therefore, called sympathomimenic drugs.

Sympathomimetic drugs have little or no effect on the ciliary muscles and hence may be used without the accompanying complication of cycloplegia. In the eye, these drugs will act on receptors in the peripheral blood vessels and dilator pupillae (Vale & Cox, 1984). Sympathomimetic agents are those produced by the sympathetic adrenergic nerves (Dipalma, 1976). Catecholamines are the main substances responsible for the stimulation of the majority of the structures innervated by post-anglionic sympathetic nerves.

Parasympatholytic agents can be divided into:

- Those that block the motor end-plate of post-ganglionic parasympathetic nerve fibres in smooth and cardiac muscles. These structures are stimulated by muscarine and blocked by the atropine group of drugs.
- Those that block the acetylcholine at the automatic ganglia of both the parasympathetic and sympathetic nervous system. Nicotine in small doses stimulates ganglionic transmission, with the action being opposed by ganglionic blocking agents.
- Those that block both the motor end-plate of skeletal muscles and the central nervous system (Newell & Ernest, 1974).

Parasympatholytics bring about mydriasis by competing for the same receptors as acetylcholine, occupying them, and thus rendering the acetylcholine ineffective, that is, it has the same affinity as acetylcholine for the receptors but different intrinsic activity (they are acetylcholine receptor blockers). They produce mydriasis by paralyzing the sphincter pupillae and decreasing accommodation through paralysis of the ciliary muscles.

Ganglionic blocking agents are agents that block the transmission of impulses across both sympathetic and parasympathetic automatic ganglia. They are used mainly in the treatment of hypertensive cardio-vascular disease to reduce peripheral resistance by decreasing sympathetic tone to vascular tone. The ganglionic blocking agents' ocular side effects constitute their main ophthalmic interest as the conjunctival blood vessels and pupils are dilated (Newell & Ernest, 1974).

**Clinical Uses of Cycloplegics**

A state of paralysis of the ciliary muscles is called cycloplegia. It may be produced by drugs instilled into the cunjunctival sac, including atropine, homatropine, scopolamine, and tropicamide. These also paralyze the sphincter muscle of the iris causing a dilation of the pupil. For this reason, they are also called mydriatics. Most drugs which dilate the pupil also paralyze accommodation to some extent.

Both these properties – cycloplegia and mydriasis – are utilized in the estimation of refractive errors. By paralyzing the parasympathetic nerve supply, all accommodation for near sight can be abolished and refractive errors which before were latent are made manifest. The dilation of the pupil moreover makes the technique of estimating the error easier and helps to allow a thorough and easy examination of the interior of the eye (Elder, 1993)

**Cycloplegic Refraction**

A cyclolegic agent should be used for refraction in children of pre-school age and for any individual in whom subjective responses are unreliable, including those who are illiterate, intellectually challenged or experiencing a language barrier.

**Comparison of Cyclolegic and Non-Cycloplegic Retiniscopy**

Young et al (1971) compared the non-cycloplegic and cycloplegic ametropias of Inuit children between six and fifteen years of age. The Inuit and the Chinese have a racial relationship and have similar iris pigmentation. Either three drops of cyclopentolate 1 percent were instilled ten minutes apart, or two drops of cyclopentolate 1 percent plus one drop of tropicamide 1 percent were instilled ten minutes apart. The author did not explain the reason for using tropicamide instead of cyclopentolate. A minimum of forty minutes was allowed for cycloplegia to develop before refraction was performed. The researchers found that the value of E (that is, the difference between the refractive error found before and after cycloplegia) increased with hyperopia. Their findings are summarized in Table 1.

In a separate study, Hiatt et al (1973, p. 76) recruited 130 subjects from clinic and private practice populations in Tennessee. Although the ages of the subjects ranged from six to forty-one years, 87 percent were under fourteen years of age. Two drops each of cyclopentolate 1 percent and tropicamide 1 percent were instilled and this dose was repeated after ten minutes. An additional thirty-five minutes were allowed for cycloplegia to develop before the refraction was performed.

Table 1: Summary of Findings - Young et al (1971, p. 24).

| Refractive Error Under Cycloplegia | | Number of Eyes | L.E. (Latent Errors) | |
|---|---|---|---|---|
| E | (D) | | E | (D) |
| +3.0 D | | 31 | 2.06 | |
| -0.25 to -3.0 D | | 206 | 0.6 | |
| -0.26 to -3.0 D | | 71 | 0.38 | |

There was no explanation for using tropicamide 1 percent, but four drops of solution instilled at a time into each eye is likely to cause a significant loss of solution. This study found E to be greater in the six to ten year-old group than in the eleven to twenty-five year-old group and that its value diminished in older subjects. The findings of this study are summarized in Table 2.

Shultz (1975) studied the variation in ametropia induced by cyclopentolate 1 percent in 85 clinical patients aged seven to eighteen years. However no information was given about their skin and iris colouration. Two drops of solution were instilled into each eye five minutes apart. Eighty three of the 170 eyes were hypermetropic, 82 were myopic and five were emmetropic when measured under cycloplegia. Shultz (1975) also found that E increased with increasing hyperopia. Table 3 summarizes his findings. All of these studies show that E increases with increasing positive refractive errors, and decreases with increasing age.

Chan and Edwards (1993) recruited thirty-one children for their study from routine kindergarten vision screenings. Every tenth child screened was invited to participate in the study. Subjects were between the ages of three and fifteen years. Parents of the selected children gave approval for the refraction examination on their children in the optometric clinic at the Hong Kong Polytechnic.

Table 2: Summary of Findings - Hiatt, et al (1973)

| Refractive Error Without Cycloplegia (Em) | | Number of Eyes | Latent Error E. (D) |
|---|---|---|---|
| Myopia | + 1.0 D | 68 | 0.5 |
| Hyperopia | + 6.5 D | 912 | 0.5 |
| | | | 2.0 |

Table 3: Summary of Findings - Shultz (1975)

| Refractive Error Under Cycloplegia | | Number of Eyes | L.E. | |
|---|---|---|---|---|
| (E) | (D) | | E. | (D) |
| 2.00 | | 18 | 2.00 | |
| 0.00 | | - | - | |
| 0.25 to + 2.00 | | 65 | 0.75 | |
| 0.00 | | 5 | 0.00 | |
| - 0.25 to - 2.00 | | 50 | 0.00 | |
| - 2.00 | | 32 | 0.00 | |

Static retinoscopy was performed twice on every child by the same retinoscopist, once before the instillation of the cycloplegic and again forty-five to sixty minutes after the instillation of the cycloplegic. The first and second retinoscopy results were recorded on different sheets to minimize the effects of knowledge of previous findings on the second result, although the effects of the examiner's memory on the findings can not be completely excluded.

Chan and Edwards (1993) used a working distance of 67cm. During the retinoscopy, every child wore a pair of + 1.5 D plastic multicoated lenses to discourage accommodation (Bigsby, et. al., 1984). One drop of cyclopentolate 1 percent was instilled in each eye, followed by another drop five minutes later. The pupil was occluded for twenty to twenty-five minutes each time the drug was instilled. If the pupil showed no mydriasis twenty to twenty-five minutes after the initial instillation, a third drop was instilled; no child needed a fourth drop.

Chan and Edwards (1993) analyzed only the results obtained from the left eye of the children in the study. To compare their results with those obtained in previous studies, they divided twenty-seven subjects into three groups (A, B, and C) according to their cycloplegic retinoscopy findings as shown in Table 4.

Table 4: Classification of Refractive Error in Chan and Edward's Study

| Group | Spherical Equivalent of E. |
|-------|----------------------------|
| A | 0.00 D |
| B | Hyperopia of +2.00 D |
| C | Hyperopia of +2.00 D |

The retinoscopy findings of all subjects measured before and after cycloplegic refraction in each group are shown in Table 5: A B and C. The mean value of E increased with the amount of hyperopia and is the smallest in group A and greatest in group C. The results show that the maximum difference astigmatic power measured with and without cycloplegia was only 0.25D. The change in spherical component power, consequently, was the chief factor that affected the value of E.

The results obtained by Chan and Edwards (1993) support those of the previous studies. The mean value of E increases as the amount of hyperopia increased. Although the age of the subjects recruited for their studies varied, all of the comparisons were made using the youngest groups (ages six to fourteen or fifteen years). Their values of E in the myopic and hyperopic groups generally matched those of previous studies, although a smaller value for E was obtained in the high hyperopic group. They attributed this to the fact that Hong Kong Chinese children tend to have smaller amounts of hyperopia than Caucasian children (Edwards, 1991; Lam & Goh, 1991).

Table 5: Retinoscopic Results for all Subjects in Groups A, B and C

| Group | Age in Months | Sphere | Cylinder | Spherical | Sphere Equivalent | Cylinder | Spherical | E(D) Equivalent |
|-------|---------------|--------|----------|-----------|-------------------|----------|-----------|-----------------|
| | | Before Cycloplegia (D) | | | Under Cyclolegia (D) | | | |
| A | 43 | 0.00 | -2.00 | -1.00 | 0.00 | -1.75 | -0.85 | 0.10 |
| | 47 | -0.75 | -0.50 | -1.00 | -0.75 | -0.50 | -1.00 | 0.00 |
| | | | | | | Mean | Change | |
| B | 37 | +0.25 | - 1.25 | -0.375 | +0.75 | -1.25 | +0.125 | 0.50 |
| | 50 | +0.50 | - 2.00 | -0.50 | +1.25 | -2.00 | +0.25 | 0.75 |
| | 65 | +0.50 | - 1.25 | -0.125 | +1.00 | -1.50 | +0.25 | 0.375 |
| | 55 | 0.00 | - 0.75 | -0.375 | +0.75 | -0.75 | +0.375 | 0.75 |
| | 61 | +0.25 | - 0.50 | 0.00 | +0.75 | -0.50 | +0.50 | 0.50 |
| | 45 | +0.50 | - 1.25 | +0.125 | +1.25 | -1.25 | +0.625 | 0.75 |
| | 52 | +0.25 | - 0.25 | +0.125 | +0.75 | -0.00 | +0.625 | 0.50 |
| | 39 | +0.25 | 0.00 | +0.25 | +1.75 | -2.00 | +0.75 | 0.50 |
| | 44 | +0.75 | - 2.25 | -0.375 | +1.50 | -1.25 | +0.75 | 1.125 |
| | 62 | +0.75+0.50 | - 1.00 | +0.25 | +1.00 | 0.00 | +0.875 | 0.625 |
| | 54 | +1.00+1.00 | 0.00 | +0.50 | +1.50 | 0.75 | +1.00 | 0.50 |
| | 59 | +0.75 | 0.50 | +0.75 | +1.50 | 0.75 | +1.25 | 0.375 |
| | 51 | +1.25 | 0.75 | +0.625 | +1.50 | 0.50 | +1.25 | 0.50 |
| | 60 | +1.25 | 0.75 | +0.50 | +1.50 | 0.75 | +1.25 | 0.75 |
| | 49 | +1.00 | 0.00 | +0.875 | +0.875 | 0.75 | +1.375 | 0.50 |
| | 58 | +1.00+0.75 | 0.75 | +0.875 | +1.00 | -0.75 | - +1.375 | 0.50 |
| | 50 | | 0.00 | +1.00 | +0.625 | 0.00 | +1.50 | 0.50 |
| | 55 | | 0.75 | +0.625 | +0.75 | -0.50 | +1.50 | 0.875 |
| | 61 | | 0.00 | +0.75 | | 0.00 | +1.50 | 0.75 |
| | | | | | | Mean | Change | |
| C | 43 | +1.00 | -0.75 | +0.625 | +2.50 | -0.50 | +2.225 | 1.625 |
| | 60 | +2.00 | -1.50 | +1.25 | +3.25 | -1.75 | +2.375 | 1.125 |
| | 50 | +1.50 | -1.00 | +1.00 | +3.00 | -1.00 | +2.50 | 1.50 |
| | 50 | +1.75 | -1.00 | +1.25 | +3.00 | -1.00 | +2.50 | 1.75 |
| | 59 | +1.50 | -1.25 | +0.825 | +3.25 | -1.25 | +2.625 | 1.25 |
| | 63 | +2.50 | -1.50 | +1.75 | +3.75 | -1.50 | +3.00 | 1.42 |

## Comparison of Cyclopentolate versus Tropicamide Cycloplegia in Children

Egashira et al. (1993) conducted a comparison study involving ten girls and ten boys, ages six to twelve (mean age = 8.8 + 2.2 years). Of the twenty subjects, sixteen were white (80 percent), two were black (10 percent), one was Hispanic (5 percent) and one was Asian (5 percent). They found the cycloplegic refractive errors of the children ranged from + 0.25 to + 4.50 D with a mean refractive sphere (+5D) of + 1.48 to + 1.10 D using a canon 12 = 1 autorefractor. All subjects were confirmed to have normal ocular health, no strabismus or amblyopia, and were able to respond to subjective refraction.

They tested each subject twice, once with tropicamide 1 percent (Mydriacyl – Alcon, Fort Worth, T X) and once with cyclopentolate 1 percent (Cyclogyl C – Alcon, Fort Worth, T X). The average time that elapsed between testing sessions was nineteen days with a range of four to eighty-seven days. Only the right eye was tested on both visits. The study was conducted using a double masked design: an 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. Neither the investigator taking the measurements, the children being tested, nor their parents knew which drop had been instilled. After taking non-cycloplegic measurements, the researchers instilled one drop of proparacaine 0.5 percent into the subject's eye followed by two separate drops of the chosen cycloplegic agent. Proparacaine was used to increase the subject's comfort, to decrease reflex lacrimation and to increase corneal penetration by the cycloplegic agent. Systemic absorption and discomfort were minimized by asking the subject to close his/her eyes for thirty seconds after each drop of the cycloplegic agent.

Table 6 shows retinoscopy, subjective refraction and autorefraction results for all twenty subjects before drug instillation and for each drug at the generally accepted time of peak cycloplegia (tropicamide at thirty minutes and cyclopentolate at sixty minutes). Egashira et al. (1993) evaluated the refractive data using only the spherical component of the refractive error as expressed in minus cylinder form. The comparison of the cylindrical component obtained by autorefraction for each individual subject (mean = 50 for tropicamide at thirty minutes = 0.77 = 0.93D and for cyclopentolate at sixty minutes = 0.69 + 82D) showed that this measurement did not vary significantly throughout the study (students paired test; $p = 0.22$).

Although retinoscopy revealed more plus than either subjective refraction (+ 0.15D, $p < 0.005$) or autorefraction (+ 0.29D, $p < 0.001$) when no cycloplegic was used, all three methods yielded similar results when either cycloplegic agent was used (student's paired E-test $p = 0.24$).

Table 6: Refractive Data. The Spherical Component of the Refractive Error by Subjects Obtained Using No Cycloplegic, Tropicamide 1 percent at Thirty Minutes and Cyclopentolate 1 percent at Sixty Minutes Measured in Diopters

| Subject No. | Retinoscopy (D) | | | Subjective (D) | | | Autorefraction (D) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Noncycloplegic | Tropicamide | Cyclopentolate | Noncycloplegic | Tropicamide | Cyclopentolate | Noncycloplegic | Tropicamide | Cyclopentolate |
| 1 | 2.50 | 2.25 | 2.75 | 2.38 | 2.50 | 2.75 | 1.69 | 2.82 | 2.63 |
| 2 | 2.25 | 2.50 | 2.50 | 2.25 | 2.50 | 2.75 | 1.99 | 2.32 | 2.03 |
| 3 | 1.00 | 1.00 | 1.25 | 0.88 | 1.00 | 1.25 | 0.68 | 1.22 | 1.49 |
| 4 | 1.00 | 2.25 | 2.25 | 0.63 | 2.00 | 1.75 | 0.48 | 2.04 | 2.03 |
| 5 | 0.88 | 2.00 | 2.50 | 0.38 | 2.00 | 2.00 | 0.99 | 2.19 | 2.23 |
| 6 | 3.75 | 4.50 | 4.00 | 3.75 | 4.50 | 4.00 | 3.46 | 4.20 | 4.56 |
| 7 | 0.75 | 1.50 | 1.00 | 0.75 | 0.75 | 1.00 | 0.39 | 1.15 | 0.70 |
| 8 | 1.00 | 1.00 | 1.50 | 1.00 | 1.25 | 1.50 | 0.33 | 0.72 | 1.29 |
| 9 | 1.88 | 2.00 | 2.25 | 1.63 | 2.50 | 2.00 | 1.69 | 2.35 | 2.35 |
| 10 | -0.13 | 1.00 | 1.25 | 0.00 | 0.75 | 1.25 | -0.30 | 0.58 | 1.25 |
| 11 | 0.50 | 1.50 | 2.00 | 0.25 | 1.25 | 1.75 | -0.02 | 1.56 | 1.84 |

| 12 | 0.50 | 0.20 | 0.50 | 0.13 | 0.25 | 0.25 | 0.42 | 0.48 | 0.71 |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 0.50 | 1.00 | 1.00 | 0.25 | 0.75 | 0.50 | 0.08 | 0.84 | 0.64 |
| 14 | -0.25 | -0.25 | 0.00 | 0.00 | 0.25 | 0.25 | -0.18 | 0.23 | 0.26 |
| 15 | 0.38 | 1.00 | 0.75 | 0.25 | 0.75 | 0.75 | 0.29 | 0.94 | 1.11 |
| 16 | 0.00 | 0.50 | 0.25 | 0.00 | 0.50 | 0.75 | -0.25 | 0.55 | 0.87 |
| 17 | 0.38 | 0.75 | 0.75 | 0.25 | 0.50 | 1.25 | -0.02 | 0.43 | 0.90 |
| 18 | 1.13 | 1.75 | 1.75 | 0.50 | 1.75 | 1.75 | 0.59 | 1.76 | 2.11 |
| 19 | 1.38 | 2.75 | 2.75 | 1.38 | 2.75 | 2.75 | 1.21 | 2.38 | 2.73 |
| 20 | 0.63 | 0.75 | 1.25 | 0.38 | 1.00 | 0.50 | 0.68 | 0.84 | 0.71 |
| Mean | + 1.00 | + 1.50 | + 1.61 | + 0.85 | + 1.48 | + 1.54 | + 0.71 | **+1.48** | **+1.62** |
| ± SD | ± 0.97 | ± 1.06 | ± 1.00 | ± 0.98 | ± 1.08 | ± 0.98 | ± 0.92 | **±1.01** | **±1.01** |

Autorefraction and subjective refraction were not statistically different under any of the three conditions (student's paired E test; $p = 0.05$) (Sherri, et. al, 1993).

## USES OF CYCLOPLEGICS

### Ciliary Spasm

Ciliary spasm is often controlled using cycloplegic agents. This is a common condition noticed after the completion of the refraction by a subjective technique, when examination discloses a remote near point of accommodation or the punctum proximum is remote for the individual's age indicating a hypertonicity of the ciliary muscle (Gettes, 1961).

### Uveitis

In the treatment of anterior uveitis, atropine becomes of help as a mydriatic as well as a cycloplegic agent. This provides comfort by relaxing the ciliary muscles which spasm in anterior uveitis. A short acting mydriatic such as tropicamide and cyclopentolate is also needed to prevent the formation of posterior synechia (that is, adhesion of the iris to the anterior surface of the crystalline lens) by maintaining pupil mobility. In mild cases of chronic anterior uveitis, however, the mydriatic can be instilled once daily at bedtime to prevent difficulties associated with accommodation during the day. Note the pupil should not be kept in a fixedly dilated position in chronic anterior uveitis (Kanski, 1988). Kanski (1988) also supports the use of intensive topical mydriatic therapy to break already formed synechia due to the fact that the synechia is unwanted because it interferes with the normal pupil action leading to pupil block glaucoma as a result of seclusic pupillae (Kanski, 1988).

### Occlusion

Management of amblyopia may involve the use of atropine if cycloplegia will reduce the acuity of the good eye below that of the amblyopic eye, thereby avoiding the mechanical and cosmetic nuisance of patching. However, prolonged occlusion is not of benefit if the amblyopic eye is fixed eccentrically.

### Higher Centres

Parasympatholytics can decrease muscle tremor and stiffness in Parkinsonism (Paralysis agents). This is attributed to the antagonism of acetylcholine (ACH) at the central synapses (Dipalma, 1976).

### Arterioles and Capillaries

The vasoconstriction effect of mydriatics helps to control bleeding from capillaries and small arterioles but is ineffective against haemorrhages from large vessels. During most ophthalmic operations, it is the oozing of blood from these vessels that obscures surgical details, hence the preliminary use of epinephrine is still of considerable importance in eye surgery (Havener, 1975)

**Bronchi**

The smooth muscles of the bronchioles are slightly relaxed by tropicamide and cyclopentolate, thereby blocking the constrictor effects of the vagus nerves. Their dilator action is minimal and is seldom used in the treatment of bronchitis, although they may occasionally be of help (Dipalma, 1976).

**Factors Affecting the Choice of a Cycloplegic**

Age: the amplitude of accommodation in children is always greater than that of adults. For instance, at eight years of age, the dioptric power of the eye can be as high as 12.00D while at the age of twenty, it falls to 11.00D. At 30 years it decreases to 9.00D and at 50 years it is less than 2.00D. In other words, the younger the patient, the more potent the drug must be in action. It is important that younger children are first examined for the presence of a muscle imbalance or muscle anomaly. For this age bracket, however subjective examination and responses are usually unreliable and the utility of a more potent cycloplegic agent cannot be ignored. At the same time, in young children short acting cycloplegics are sometimes irritative and may actually induce a temporary spasm of accommodation.

Appearance of the Anterior Chamber: a shallow anterior chamber should be regarded with suspicion no matter the patient's age. In the course of an eye examination, any shallow anterior chamber presupposes potential narrow angle glaucoma. This can usually be confirmed with the use of tonometer-determined intra ocular pressure (IOP) and gonioscopy to assess the visibility of the angle of the anterior chamber.

Pigmentation of the Iris: it is quickly evident to an examiner with much clinical experience that greatly pigmented irides, such as are seen in non-Caucasians, will dilate with greater difficulty than the lightly pigmented eye. The fair skinned blue eyed patient will respond to weaker dilution much more readily than will darker skinned-darker eyed patients (Okafor, 1995).

Occupation: excluding the young child, in using cycloplegic agents in therapeutic for diagnosis the more committed or in-demand an individual is, the greater the need for an agent with rapid restoration of accommodation so that the student or employed person can quickly return to their occupation.

**The Drug Tropicamide**

**Structure and Chemistry of Tropicamide**

Wilder (1961) gave tropicamide the clinical name N-ethyl (-2-phenyl) N-(4-pydryl methyl)–hydracrylamie but regarded tropicamide as less satisfactory than either homatropine (5 percent) or cyclopentolate (1 percent). This was based on the fact that an ideal cycloplegic should provide: maximum relaxation of accommodation and mydriasis, rapid onset of action and rapid attainment of maximum effect, short duration and rapid recovery, consistency in its efficacy, and freedom from toxicity, irritation or sensitivity. Concurring with Goodman and Gilman (1975) observed that tropicamide is a synthetically prepared derivative of tropic acid which is a constituent of, but still dissimilar from the belladonna alkaloids (Goodman & Gilman, 1975).

According to the British Pharmacopaedia (1973), tropicamide is N-ethyl-4-(4–piperidyl methyl) tropicamide. It contains not less than 99.0 percent, not more than 101.0 percent, and not more than the equivalent of 101.0 percent $C_{17}H_{20}N_2O_2$ calculated with reference to the dried substance which is a white or almost white crystalline powder that is odourless or almost ordourless. It is soluble in 160 parts of water in 3.5 parts alcohol (95 percent) and 2 parts chloroform and has a molecular weight of 284.4.

Tropicamide along with Lachesine, Dibutoline, and Oxyphenonium are synthetic analogues of atropine. They are all muscarine blocking agents and therefore show similar effects to atropine. These properties are also attributable to cyclopentolate. Also much like atropine, tropicamide does not affect nerve impulse and does not prevent the release of acetylcholine (ACH) (Vale & Cox, 1984). Tropicamide (0.5 percent) and (1 percent) are available in both single and multidose forms.
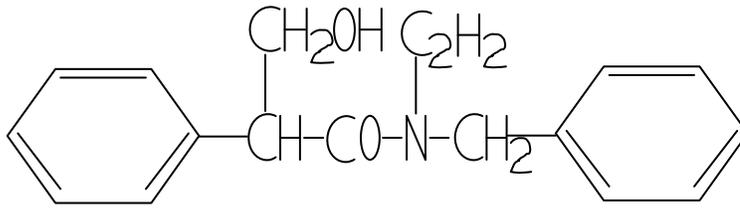
Figure 1: Structure of Tropicamide

## Mode of Action

Tropicamide causes mydriasis by:

- Unbalancing the system in favour of the sympathetic side;
- Diminishing the responsiveness of the sphincter pupillae to parasympatholytic activity

Tropicamide thus belongs to the parasympatholytic drug group and is an antimuscarinic agent that acts as a competitive antagonist to acetylcholine and other muscarinic drugs. The actions of acetylcholine are inhibited by tropicamide at the structures innervated by the postganglionic cholinergic nerves of certain smooth muscles. Tropicamide and all others in the antimuscarinic class block the action of the sphincter muscle of the iris and the ciliary muscles of the lens to cholinergic stimulation, thereby dilating the pupil and inhibiting accommodation (cycloplegia).

## Action in the Eye

The interest in tropicamide results from its mydriatic action which is known to be greater than its cycloplegic action. When a 0.5 percent or a 1 percent solution of tropicamide is used, mydriasis is rapid in onset reaching its peak in 15–30 minutes with a return to normal occurring in 8–9 hours. Tropicamide's cycloplegic action is relatively weak reaching its maximum effect after 25 minutes and with full amplitude having returned after 6 hours (Vale and Cox, 1984).

Merill et. al. (1960), as well as Stine (1960), report that the 0.5 percent solution is inadequate for routine refraction and that maximum cycloplegia can be attained with the 1 percent solution in 20 to 30 minutes. In their study, Merill, Goldberry and Zavell compared similar age groups where 1 percent tropicamide, 1 percent cyclopentolate and 5 percent homatropine had been used. Tropicamide appeared to be the most effective drug, in that it produced the least amount of residual accommodation 30 minutes after instillation (Merill, et al., 1960; Stine, 1960).

Gettes (1961) showed that tropicamide (1 percent) is an effective cycloplegic agent provided examination is performed 20 – 30 minutes after the instillation of a second drop. Using this time interval, the agent was effective in 90 percent of 96 eyes. If the elapsed time is extended to 45 minutes, its effectiveness drops to 79 percent, and at 45 minutes the cycloplegic was inadequate for clinical purposes because practically every case showed more than 3.50D of accommodation. Gettes also stated that the 0.5 percent solution of tropicamide is a very effective mydriatic preparation and is indicated when rapid and short-acting dilation is desired. There is generally a rapid recovery of accommodation and the cycloplegic effect is gone in 2 – 4 hours with the complete return of accommodation within six hours.

In their quest for an ideal cycloplegic agent, Gettes and Belmout (1961), compared and evaluated the so-called short-acting cyclopentolate hydrochloride and homatropine. This comparison was based on the following (Table 9):

(1)     The effectiveness of the cycloplegic;
(2)     The duration of cycloplegia; and
(3)     The rapidity of the return of accommodation.

Table 7: One drop of Tropicamide 1 percent Solution

| Time after Instillation(minutes) | No. of eyes instilled | Number Effective | % Effective |
|---|---|---|---|
| 20 – 25 | 30 | 16 | 53 |
| 20 – 30 | 75 | 30 | 40 |
| 20 – 35 | 108 | 43 | 38 |
| 20 – 40 | 133 | 47 | 35 |
| 20 – 45 | 145 | 48 | 33 |
| 20 – 60 | 266 | 48 | 29 |

Table 8: Two drops of Tropicamide 1 percent Solution

| Time after Second drop(minutes) | No. of eyes instilled | Number Effective | % Effective |
|---|---|---|---|
| 20 – 25 | 44 | 44 | 100 |
| 20 – 30 | 70 | 65 | 93 |
| 20 – 35 | 76 | 69 | 90 |
| 20 – 40 | 96 | 76 | 79 |
| 20 – 60 | 106 | 76 | 74 |

Table 9: Comparing the Time and Duration of Adequate Cycloplegia, and Time for Recovery from Cycloplegia of the Drugs

| Drug (1%) | Time and Duration of Adequate Cycloplegic (minutes) | Time for Recovery (hours) |
|---|---|---|
| Homatropine in Hydroxy amphetamine hydrobromine | 40 – 90 | 36 – 48 |
| Cyclopentolate | 25 – 75 | 6 – 24 |
| Tropicamide | 20 – 35 | 2 – 6 |

A series of patients had 1 percent tropicamide instilled into one eye with a second drop at least five minutes later. In the opposite eye, one drop of 1 percent cyclopentolate was instilled. Another group had 1 percent tropicamide in one eye and homatropine in the other eye. In all cases, where tropicamide was instilled in one eye and one of the other drugs in the other eye, recovery of accommodation and the ability to read fine print were more rapid in the eye with tropicamide. Both examiners noted the similarity of patient complaints, namely: "I can read with one eye but the other eye is blurred and has a larger pupil."

The fact that tropicamide is an effective mydriatic can not be over stressed. Hadded et. al. (1970) found that two drops of 2.5 percent phenylepherine produced as much mydriasis as did one drop of 10 percent phenylepherine. Among younger groups, however, one drop of 0.5 percent tropicamide produced faster and greater mydriasis than either dose phenylepherine.

**Adverse Reaction to Tropicamide**

For many years, there have been wide-spread reports in the literature related to the toxicity of cycloplegic agents used during refraction. Most of these, however, offer evidence other than a symptomatic description of the intoxication (Hoefnagel, 1961; Mackenzie, 1971).

Correspondence with the manufacturers, Alcon Labs, led to a simple report of what may be termed an adverse reaction: a patient fainted after instillation of one drop of 0.5 percent tropicamide (Wahl, 1969). Wahl (1969) and

Garston (1975) reported that 0.5 percent of 22 subjects who received 0.5 percent tropicamide complained of a stinging sensation in the eye and irritation of the corneal tissue.

Smith, in 1975 reported that tropicamide, artropine and homatropine had no significant effect on the heart rate of frogs and rabbits, while Jennings and Sullivan (1986) likewise reported no systolic or diastolic blood pressure and pulse increase for any of the treatment groups. A similar study, however, did find a decrease in systolic and diastolic blood pressure and pulses in patients given 1 percent tropicamide, as well as in a second group receiving 10 percent phenylepherine at different time intervals (Brown et al., 1980).

Neither Leopold (1966) nor Havener (1970), however, reported any ill effect from this medication. In 1961, Gettes reported that having used this drug in all age groups, including children as young as six years of age, no local or systemic toxic effects were observed. Nonetheless, Lyle and Hopkins (1977) stated that adverse reactions to tropicamide in the literature are "conspicuous by their rarity."

## Tropicamide and Iris Pigmentation

Physicians and optometrists have generally held the belief that heavily pigmented dark irides are more difficult to dilate, while lightly pigmented irides dilate more easily and faster resulting in a large papillary aperture (Dillon, et. al., 1977; Havener, 1975). It is thus generally accepted that mydriatic and cycloplegic agents are required in both greater quantity and higher concentration to obtain an adequate degree of mydriasis and cycloplegia in dark irides (Dillon, et. al., 1977; Harrison and Galin, 1971), and that this has the potential to increase the risk and severity of possible adverse reactions.

Gettes, in 1961, noted that the eyes of those with dark skin and eyes were more difficult to dilate with 0.25 percent, 0.5 percent and 0.1 percent solutions of tropicamide, but stated that optimal dilation was approximately the same for all subjects (both those with light and dark irides) using 0.5 percent tropicamide. Emiru (1971) also felt that dark African pupils dilate more sluggishly in response to a mydriatic than those of lighter skinned races or albino Africans. Conversely, Richardson, (1982) reported that contrary to previous beliefs, iris pigmentation is not a factor in the degree of dilation achieved, but that a light iris is significantly larger than a dark iris prior to any instillation.

## Mydriasis and the Precipitation of Glaucoma

Increases in intra-ocular pressure by most cycloplegic mydriatic drugs have been noted to occur in eyes in which the filtration angle remains open during mydrasis. Cyclopentolate and tropicamide have similar effects in patients being treated with pilocarpine. In normal eyes, as well as those with ill-treated open angle glaucoma, these drugs have a relatively weak effect on intra-ocular pressure (Portney & Paurcell, 1995). Anytime the dilator pupillae relaxes, however, the resistance within the trabecular meshwork increases and the drainage of aqueous is slowed which results in an increase in intra-ocular pressure (IOP) (Cohen and Hajoft, 1982).

The most conspicuous and frequently mentioned adverse effect of ocular mydriatics is the possibility of inducing a rapid elevation in intra-ocular pressure (Terry, 1977; Diane et. al., 1980; Rengstoff and Daughty, 1982). Any agents that dilate the pupils also increase susceptibility to an attack of glaucoma, though the risk of inducing a glaucomatous attack is rare. In their study Rengstoff and Daughty (1982), showed that of 58 narrow-angled eyes dilated with 0.5 percent tropicamide, 33 percent (19) developed angle closure and a significantly increased IOP. Aviner (1977) found that three of six eyes examined with a shallow anterior chamber and narrow but open angles had raised intra-ocular pressure which was subsequently relieved through emergency measures. Portney and Pupillae (1995), studied intra-ocular pressure among fifty patients with open-angle glaucoma and found less than a five mmHg increase forty minutes after two drops of 1 percent tropicamide. This outcome, an increase in intra-ocular pressure in an eye predisposed to narrow angle glaucoma, occurs because the dilated iris blocks drainage of the intra-ocular fluid from the angle of the anterior chamber (Terry, 1977; Gyton, 1981).

In 1958, Becker and Thompson reported using mydriatics as a provocative test for patients with narrow-angle glaucoma. They found that only 15 of 58 patients (28 percent) exhibited a rise in intra-ocular pressure of eight mmHg or more and that only 14 of 32 eyes with narrow angle glaucoma found to be closeable (that is, with a history of closure in the other eye) showed the rise. They did not report any cases of closure during their testing.

It is important here to highlight the views of Harris (1968) and Havener (1975). According to Harris, no mydriasis provocative test for angle closure using a cycloplegic agent can be considered positive until angle closure is determined by gonioscopy. Havener noted that he observed increased pressure after mydriasis as a positive result of a

provocative test. Certainly, it is better to discover glaucoma through such an increase and to treat it, then to watch the patient go blind ignoring the debility of the disease (Havener, 1975).

## Cyclopentolate

Cyclopentolate is the most widely used contemporary cycloplegic with well-recorded and broad recognition in ophthalmic diagnosis and therapy. It is generally known as cyclopentolate hydrochloride (cyclogyl), and is also a mydriatic agent. It is a synthetic anti-spasmodic agent which produces rapid, intense cycloplegia and mydriasis of moderate duration after topical ocular administration. The compound is dimethylaminoethyl (1-Hydroxycyclopentyl) phenylacetate hydrochloride with the following structural formula:
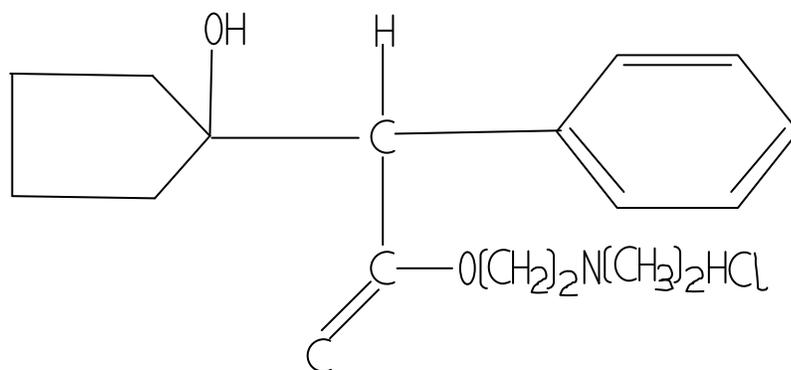


Figure 2: Structure of Cyclogyl

Cyclogyl is a parasympsatholytic drug. It is similar to artropine and homatropine in action; a similarity which relates to its chemical property as a basic ester and quartenary derivative of β-hydroxyl acid - β-dimethylaminoethyl - (1-hydroxycyclopentyl) - phenylacetate hydrochloride. Structurally, cyclogyl shares a dimethylated side chain [–N-$(CH_3)_2$] in common with many tranquilizers and psychoactive drugs and some hallucinogens.

## Physical Properties

Cyclopentolate hydrochloride is a white odourless crystalline with a solid melting point of $137 - 141^{o}C$. It is very soluble in water and freely soluble in alcohol. The pH of 1 percent solution is $5.0 - 5.4$.
    The compound can be identified by dissolving 20mg of cyclopentolate hydrochloride in 10ml of water, and adding 2 drops of Nitric acid and 1ml of Silver nitrate. A curdy white precipitate will form which is insoluble in dilute nitric acid, but soluble in dilute ammonia solution (showing the presence of Chloride). This should be transferred into a 60ml separating funnel. Extract 0.5g of cyclopentolate hydrochloride and dissolve it in 10ml of water. Add 2.5g of potassium carbonate and extract the mixture with two 10ml portions of water. Dry the water extract above anhydrous potassium carbonate and filter it through a dry filter paper. Add about 0.2ml of dimethyl sulphate to the dry water solution and allow the reaction mixture to stand at room temperature for 2 hours. Filter the mixture, re-crystallize the solid in acetone and dry it in a vacuum desicator over phosphorus pentaoxide. The methyl sulphate derivative melts with decomposition at 139– 143C.

## Mode of Action

Up to Twelve Years of Age

Usually only one drop of the 1 percent solution is necessary, but it should be repeated if little effect is measurable after 15 minutes. Retinoscopic refraction may then be performed in 40 to 60 minutes (or sooner, if desired, when the maximum cycloplegic effect is obtained earlier than this.)

Twelve Years of Age and Above

One drop of 0.5 percent solution, only repeated if there is no significant measurable in the amplitude of the accommodation within 15 to 20 minutes. This second drop is sometimes necessary in Caucasian patients with dark hair and irides. For dark-skinned adults, one drop of the 1 percent solution should be instilled, and the dose only repeated if the amplitude of accommodation is not falling at a satisfactory rate. Again retinoscopy is generally carried out after 40 – 60 minutes - the average time taken for the maximum effect of the drug to reduce the accommodation to less than 2.00D. Others have suggested, however, that where a deeper cycloplegia is not considered essential, a 0.125 percent solution, two drops of which will reduce the accommodation to approximately 1.50D (one drop to about 2.00D) in approximately 30 minutes, may be sufficient for patients between the ages of 20 and 40 years. However, it should be considered that this maximum effect requires that we restrict the use of this concentration in general practice to infrequent occasions.

## Time Course

One or two drops of the cyclopentolate solution instilled into the conjunctival sac produces a mydriasis within a few minutes that reaches it maximum in 30 – 60 minutes, and sometimes as rapidly as 15 minutes or in rare occasions, 10 minutes. Cycloplegia starts almost simultaneously with mydriasis, and also generally reaches its peak between 30 and 60 minutes, but can vary from an exceptional 10 minutes to 60 minutes or thereabout. Because of the variation in the time taken to produce maximum cycloplegia, and also in view of the fact that the duration of this condition varies from 10 to 60 minutes (averaging about 40 minutes), the amplitude of accommodation should be measured every 10 minutes, after a time lag of 20 minutes following instillation, until no further fall in accommodation is recorded.

## Depth of Cycloplegia

In almost all cases, the residual accommodation reaches 1.50D or less 40 to 60 minutes after instillation (although not infrequently, a second drop of solution may be necessary to reach this accommodation level), and it is during this interval that a retinoscopic refraction is usually performed. In practice, cyclopentolate satisfies approximately the ideal criteria for a cycloplegic or mydriatic than any other drug.

Priestly and Medine compared the depth of cycloplegia reached after one hour of instillation of two drops of 0.5 percent solution of cyclopentolate with a dosage of a 0.5 percent solution of homatropine in a group of more than 50 patients, including children and young adults. The cyclopentolate was instilled in the right eye and the homatropine in the left eye. Their results showed that residual accommodation for cyclopentlate ranged from 0.50 to 1.75D with an average of 1.25D, whereas with homatropine, the upper end of this range was 2.00D. In an endeavour to ensure that any existing anisocycloplegia did not affect their findings, the series was later executed using cyclopentolate in both eyes. Anisocycloplegia, a common occurrence, is the difference that may occur in the residual accommodation between two eyes of the same patient to the same dose of cyclolegic (often it amounts to 0.5D, but can reach 10.0D).

Rosenfield and Linfield (1986) proposed, as a measure of the degree of cycloplegia, the use of what they termed a "distance accommodation ability" measurement in which negative spherical lenses were introduced until the patient was no longer able to clearly read a line of Snellen letters. They considered it an easier test to perform than apparent near point, especially on young children. It is interesting that the average minimum near and distant accommodation were not significantly different when 1 percent and 0.5 percent cyclopentolate were compared. The residual accommodation was again found to be invariably less in these eyes when compared with homatropine recordings, where anisocycloplegia might well occur.

In another series involving eighty patients and the application of two drops of a 0.5 percent solution of the original American proprietary brand of cyclopentolate hydrochloride (cyclogyl), the average residual accommodation after one hour was found to be 1.0D. These results (with average residual accommodation measured after correction of any distant refractive error), are as shown in Table 10. Full recovery of the accommodation, without the instillation of a miotic, usually occurred within 4 and 12 hours, but in a few cases this was delayed for up to 24 hours. Reading, in practice a more important consideration than full restoration of accommodation, was usually possible after 3-4 hours. Recovery from mydriasis was shown to occur between 24 and 48 hours in all instances without the aid of a motic.

These investigations were presumably carried out on normal eyes and found no increase in intra-ocular pressures. The author made no direct comparisons of residual accommodations to those encountered using a homatropine-hydroxyamphetamine combination, formerly the most popular combination of cycloplegic and

sympathomimetic drugs used by American ophthalmologists. Rather he considered that the cycloplegic effect obtained with cyclopentolate to be either equal to or more profound than that of the combination.

As with all other cycloplegics, with the exception of atropine, distance fixation during retinoscopy is necessary to relax as much residual accommodation as possible. Measuring of the latter before and after examination may be carried out with reasonable accuracy using a +3.00D sphere monocularly with the near point rule.

Table 10: Average residual accommodation measured after correction of any distant refractive error

| Age Group (years) | Number of Cases | Residual Accommodation |
|---|---|---|
| 10 – 20 | 28 | 1.14 |
| 20 – 30 | 29 | 0.97 |
| 30 – 40 | 23 | 0.97 |

Where children under the age of seven who had previously shown allergic reaction to atropine, require cycloplegic refraction, one or two drops of cyclopentolate hydrochloride eye drops at 1 percent may be substituted, immediately followed by very careful occlusion of the canaliculi for half a minute or so (Davies, 1989).

**Medical Uses**

Cyclopentolate may be used in the treatment of coeneal ulceration, iritis, iridocyclitis and keratitis. For these conditions, one or two drops of the 0.5 percent solution instilled every 6 – 8 hours, to prevent the formation of posterior synechiae and "rest" the painful ciliary and sphincter pupillae muscles, can be helpful. Cyclopentolate is also useful in the treatment of choroiditis. For all these conditions, it acts as a mydriatic.

For the prevention of lenticular adhesions, or, in conjunction with the use of miotics, cyclopentolate can be used to break or prevent adhesions formed during and after infections. No significant variation of intra-ocular tension has been reported from its use in this way, although it is advisable to neutralize any cycloplegia in other patients in whom early unrecognized glaucomatous changes may be present. When breaking down lenticular adhesions, one or two drops of a 0.5 percent solution are instilled, followed six hours later by one or two drops of a 2 percent solution of pilocarpine nitrate; this alternating treatment is repeated daily.

**METHODOLOGY**

This research was based on the practical or clinical examination of subjects in whose eyes the agents/drugs (cyclopentolate and tropicamide, 1.0 percent solutions) were instilled. The subjects included young adults, both those attending and not attending university, between the ages of 17 and 29.

Since considering all individuals in a population of interest was unnecessary given the use of statistical sampling, random sampling, which gives every individual an equal chance of being selected, was used. Estimates made based on these samples can subsequently be generalized to the entire population being studied. All subjects were first asked to undergo a fundal examination to eliminate pathologies and a preliminary examination to estimate squint, eccentric fixation, anisocoria, etc. Those found to be fit for the study were then subjected to the test and informed on a step-by-step basis of what to expect after drug instillation into the eyes. Several control measurements (visual acuity, power of refractive error, if any, amplitude of accommodation, etc.) were made before and after instillation.

**Study Population**

The population in this study consisted of young adults aged between 17 and 29 years, both male and female who were myopes, hyperopes, astigmats or even emmetropes, selected from within and around the university community. Carrying out the research on all the young adults in the study area was impossible and so a method of random sampling was employed. This method provided every member of the community an equal opportunity of being selected for testing. The final sample was comprised of 25 individuals who were screened to rule out pathologies after their consent was obtained. Participants were made aware of the initial discomfort, such as stinging and/or irritation, which might be experienced immediately after instillation.

**Data Collection**

Measurements were made of the subjects' pupil size, far and near visual acuity (VA), phoria at far and near, and amplitude of accommodation (AA) before and after instillation of each of the two drugs. These measurements were central to the proper analysis of the results obtained after drug instillation. Members of each group were given one of the two drugs on their first visit and the second drug on their second visit, two weeks later. On each occasion, one drop of the drug used was instilled into the inferior cul-de-sac of one eye. Only one eye was tested so that the untested eye could still compensate for the reduced VA and other discomforts of the tested one. Each instillation was monitored at a regular interval of five minutes until the time of recovery.

Application of the drugs on each occasion was with a dropper held far enough from the conjunctiva so as to count the number of drops and to prevent the muzzle of the dropper from touching the conjunctiva, thus avoiding contamination. The size of the dropper used in each instillation was the same, and equal efforts were made to apply uniform pressure to the squeezer in the drug administration.

The measurement of pupil size before and after instillation was done under normal illumination conditions (although the term "normal illumination" varies from one person to another). Regardless, the illumination was held constant. Five minutes after the initial pupil size measurement, the drugs were instilled and pupil size and refractive error were measured at regular five minute intervals until maximum mydriasis and cycloplegia were reached. The other measurements were also repeated at these intervals and the time at which recovery started was recorded.

**Instruments/Materials for Data Collection**

The instruments and materials used in this research included:
- Penlight/torchlight
- Streak retinoscope to determine refractive errors
- Hand-held direct ophthalmoscope
- Inter-pupillary distance (IPD) rule
- Phoropter for measuring amplitude of accommodation and phoria
- Snellen acuity chart at 6m (20ft) for far visual acuity (VA) measurement
- Reading chart at 40cm for near visual acuity (VA) measurement
- Mydriacyl (Tropicamide) 1 percent solution
- Cyclogyl (Cyclopentolate) 1 percent solution ⎫ Alcon Belgium

**Pupillary Response**

A penlight was held 10cm in front of the eye for the swinging flash-light test to determine papillary response to light stimulus. Each pupil was alternately illuminated from an oblique angle using the penlight, at least thrice, to evaluate the light reflexes of the treated eye. During the test, the presence of papillary abnormalities was ruled and an evaluation of direct and consensual pupillary reflexes was performed. Positive light responses were abbreviated as PERRLA, that is, pupil equal, regular, reacts to light and accommodation.

**Measuring Pupil Size**

The inter-pupillary distance (IPD) rule was used to measure pupil size with a hand held magnifier to adequately assess pupil diameter.

**Ophthalmoscopy**

This is an objective technique used for the exclusive observation of the interior (vascular and neurological) structures of the eye. In doing this, the ophthalmoscopist's interest is in the size and shape of the optic disc, the clarity and sharpness of the margins, the size of physiological cupping in relation to the disc, muscular reflex, the integrity of blood vessels, and pigmentation. The ophthalmoscope is the standard instrument used for this test and the one used here was a hand-held direct ophthalmoscope. In performing the examination, the instrument was held in the right hand

to view the right eye, and in the left hand to view the left eye. This is a monocular examination done under dim illumination.

## Retinoscopy

A retinoscope was used for an objective determination of refractive errors. Each subject was seated six meters from the far VA chart and instructed to fixate their eyes on the chart. Like in ophthalmoscopy, the retinoscope is held in the right hand to scope the right eye and vise versa, under dim illumination. The scoping is performed along the two meridians (vertical and horizontal) and obliquely to determine the astigmatic error. The lenses in the phoropter are added in quarter increments until neutrality is reached. At the point of neutrality, the dioptric equivalent of working distance is subtracted from the total lenses added to arrive at the number of refractive errors.

## Measurement of Amplitude of Accommodation

The amplitude of accommodation was determined using the phoropter. There are two methods of doing this: push-up-to-blur and minus-lens-to-blur. The latter was used in this study and involves adding or subtracting lenses in 0.25D steps while the subject fixates on the test target placed 33cm in front of the eye (monocularly). The addition or subtraction of lenses was stopped as soon as the subject reported a noticeable blurring of the letters and 2.50D was added above the total lenses in place and recorded as the amplitude of accommodation.

## Phoria Measurement

Again, the phoropter was used to determine the phoria at far and near. To determine the distant phoria, the target was the 6/6 (20/20) Snellen letters. The subject was told to close his/her eyes and the dissociating device (6D prism up) and the measuring device (15D prism base-in) were positioned before the left and right eye respectively. The base-in prisms were reduced until the vertical alignment of targets was obtained. The base-in prisms that remained were recorded as diopters of exophoria; while base-out prisms were recorded as diopters of esophoria. At near, the testing distance was 40cm while fixating the Snellen letters. All other procedures were repeated at far.

## Visual Acuity (VA)

The Snellen acuity chart and reading card were used to measure the far and near VA. Distance acuity was measured at a distance of 6m which is the optical infinity. The subject was asked to read the chart horizontally moving from one letter to the next and the point at which he or she stopped seeing the letters was recorded as the VA at far. The reading card was kept at a distance of 40cm and the subject was then instructed to read the paragraphs. The last paragraph he/she was able to read was recorded as the VA at near.

## Data Analysis

A number of statistical analyses, including the t-test, were used to analyze the data collected in this study. The data was analyzed to compare the cycloplegic effect of tropicamide and cyclopentolate ($t = 0.05$ level of significance was used unless otherwise stated). All of the results were then tabulated for easy understanding and percentage values were used where necessary.

## DISCUSSION

Tropicamide and cyclopentolate are cycloplegic drugs with common mydriatic and cycloplegic actions, although the strength and depth of these actions differs.

In the course of this study, both drugs were found to have a significant effect on the action of the sphincter pupillae muscle which controls the size of the pupil when one to two drops of the 1 percent solution of each were instilled into the cul-de-sac. A more significant effect was observed when the 1 percent solution of cyclopentolate was used. Of the 25 eyes tested with tropicamide, 19 showed a pupillary size increase from 3mm to 6mm; three showed an increase from 3mm to 4.50mm; two showed an increase from 3mm to 5.00 to 5.50mm; and one showed an increase to 6.50mm. When the 1 percent solution of cyclopentolate was used, 13 of the 25 subjects showed an increase in pupil

size to 6.50mm while 12 had their pupil size increase to 6.00mm from the initial size of 3mm. This represents an average additional increase of 0.48mm in pupil size compared to that obtained with tropicamide

It is generally accepted that pupil size can affect visual acuity, hence the larger the blur circle, the more likely stimulation is to overlap upon the immediate cone and eliminate the discrimination of two points. The smaller the blur circle can be made, the closer two points of regard can be and still not fall upon the intermediate retinal element (Borish, 1970). In other words, a larger pupil size results in a larger blur circle and consequently a blurrier image, and a smaller pupil size results in a sharper image and a smaller blur circle. This lowers and raises the visual acuity respectively. The size of the blur circle is affected by the refractive status and the size of pupil and any drug that affects the accommodative mechanism can also affect the refractive status, the blur circle and visual acuity.

In this study, the combined cycloplegic and mydriatic actions of tropicamide and cyclopentolate reasonably affected the visual acuity of the tested persons. A greater change in visual acuity was noticed at near than at far. Comparatively, the effect of the action was stronger and deeper with the instillation of one drop of 1 percent cyclopentolate than with tropicamide. Cyclopentolate reduced the visual acuity by two lines more than that of tropicamide at far, and by an average of three lines more at near.

In the measurement of phoria, both drugs affected the phoria at near and far. At both distances, the phoria tended towards esophoria or less exophoria though this was more pronounced at near than at far. And at either distance, cyclopentolate produced a greater and stronger effect than tropicamide. At far, a drop of 1 percent solution of cyclopentolate produced a mean change in phoria of 1.2 eso from an initial 0.8 exo, while tropicamide produced a mean change of 1 eso from an initial 0.8 exo, resulting in a mean variation of 0.4 eso between the effects of tropicamide and cyclopentolate. At near, one drop of the 1 percent solution of cyclopentolate produced a mean change of phoria of 1.56 exophoria from an initial 4.72 exophoria, while the 1 percent solution of tropicamide produced a mean change in phoria of 1.28 exo from an initial 4.72 exo, resulting in a mean variation of 0.28 exo between the effects of cyclopentolate and tropicamide.

The action of cycloplegic drugs is mainly directed at the accommodative function of the eye(s). In this study, the instillation of one drop of 1 percent solution of cyclopentolate and tropicamide certainly affected the amplitude of accommodation (AA) of the eye(s), with a significant difference between the reduction obtained with cyclopentolate and that obtained with tropicamide. One drop of 1 percent solution of cyclopentolate reduced the amplitude of accommodation from an average of 9.25D to an average of 3.41D (a 63 percent decrease) while one drop of 1 percent solution of tropicamide decreased the amplitude of accommodation from an average of 9.25D to an average of 3.93D (a 56 percent decrease). This represents a difference of 0.52D in the mean change in amplitude of accommodation or a difference of 5.6 percent.

Based on the intermittent measurement of the pupil size after instillation, it was determined that out of the 25 eyes tested with 1 percent tropicamide, mydriasis started after five minutes in nine eyes; after ten minutes in another nine eyes; after eight minutes in three eyes; after seven minutes in another three eyes; after six minutes in one eye. When one drop of 1 percent solution of cyclopentolate was used, eight out of the 25 tested eyes showed papillary dilation after ten minutes; seven dilated after 11-12 minutes; five dilated after 13-15 minutes; four dilated after 8-9 minutes and only one pupil took just five minutes to dilate. Since mydriasis and cycloplegia start almost simultaneously (Davies, 1989), the average time of onset with one drop, 1 percent solution of tropicamide was 7.44 minutes compared with an onset after 10.92 minutes with one drop of 1 percent solution of cyclopentolate; a mean difference of 3.48 minutes in the on-set time of action between the two drugs. On average, their actions peaked after 19.4 minutes and 23.84 minutes, respectively. The difference in the mean time of maximum actions between the two drugs was 4.44 minutes.

By intermittently measuring pupil size after peak mydriasis, it was determined that papillary dilation started decreasing in 1 hour and 48 minutes after the onset of mydriasis when one drop of 1 percent solution of tropicamide was used and in 2 hours and 8 seconds when one drop of 1 percent cyclopentolate was used. The mean difference in the recovery time of the two drugs was 36 minutes.

During the course of this study, no serious adverse effects were observed with the instillation of one drop of 1 percent solution of tropicamide, except for a little transient pain felt in the eye immediately after instillation. A greater number of those tested complained of this pain when either of the drugs was used. All subjects noted the usual blurring of vision, especially at far.

In addition to the side effects noticed with tropicamide, a few systemic reactions were exhibited when some subjects were tested with one drop of 1 percent solution of cyclopentolate. Five subjects reported that they felt like they took two tablets of chloroquine; four reported feeling sleepy after the test, while seven felt nauseous. The fundoscopic examinations, however, showed no changes.

## CONCLUSION AND RECOMMENDATIONS

The need for optometric diagnostic and/or therapeutic agents is an utmost necessity in everyday medical and paramedical practice, especially if their health benefits outweigh complications during and after use. The benefits and complications of treatments can be assessed in terms of onset of drug action, duration of action and the time after which the drug effect starts diminishing until the patient regains his/her normal health condition. Other factors to be considered are the presence and absence of ocular and systemic reactions, drug-to-drug interaction, and the strength and depth of the desired effect.

In this study which compared the cycloplegic effect of tropicamide and cyclopentolate in their one drop, 1 percent solution concentration, cyclopentolate is more efficacious in achieving the desired effect as demonstrated by its action on pupil size, far and near visual acuity, far and near phorias and amplitude of accommodation for the 25 study subjects. The one drop 1 percent solution of cyclopentolate, for instance, reduced amplitude from an initial 9.25D to an average of 3.41D compared to the 3.93D obtained with the same quantity and concentration of tropicamide. What cyclopentolate gains in strength and depth of action, however, it loses in its longer time of peak mydriasis and cycloplegia and time of recovery, which averaged 2 hours 8 seconds compared to 1 hour 48 minutes with tropicamide. Perhaps the most significant advantage of tropicamide was that it was found to have little or no adverse ocular/systemic reaction while cyclopentolate is associated with mild to severe ocular/systemic reactions such as nausea, vomiting, drowsiness, hallucination, etc.

Based on the above findings and observations, for optimal and complication free diagnostic and therapeutic procedures, the use of tropicamide in an appropriate concentration of 0.5 percent to 1 percent is recommended over the use of cyclopentolate.

## Limitations of the Study

This study encountered two main limitations in its execution. Foremost, many people are rightfully protective of their eyes as their most precious sense organ and were therefore unwilling to participate in this study. This drastically reduced the sample population in the study. Despite all the appropriate precautions having been taken, it was very difficult convincing subjects that no damage would be done by the drugs to their eyes.

It was also difficult getting the subjects commit to a second visit and a number of participants asked for financial compensation before they would comply. The length of time required before full recovery was between 8 and 9 hours which was considered too long, and this called for the limiting of the study to just the onset of recovery. Drug procurement also posed somewhat of a challenge given that these drugs are not of the over the counter (OTC) variety. Lastly, there would have been a more elaborate literature review of the study topic had there been better access to current journals and textbooks.

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[i] Dr. Desmond Eberechukwu Ihekaire is a lecturer Department of Optometry, Faculty of Health Sciences, Imo State University, Owerri, Nigeria. Dr. Ihekaire can be reached on phone: +234 80 38808858, E-mail: ihekaired@yahoo.com.