Approach to Cycloplegic Refraction

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Abstract

Children and younger adults are able to overcome some of the challenges posed by uncorrected refractive errors (particularly hyperopia) due to their robust accommodative abilities. However, this ability can significantly affect the accuracy of the assessment of their refractive error. To overcome this challenge, paediatric cycloplegic refraction is indispensable. Cycloplegic refraction is the process by which refractive errors are assessed using cycloplegic agents such as homatropine and cyclopentolate. It is indicated when determining the full hyperopic correction in the management of manifest childhood esotropia, accommodative spasm, amblyopia, anisometropia, uncompensated esophoria, and suspected pseudomyopia. It can help ensure correct vision treatment, protect visual health, and improve children's academic performance and overall quality of life. Longstanding uncorrected refractive errors in children may predispose them to strabismus (squint), amblyopia (lazy eyes), non-optimal vision, asthenopic symptoms like eyestrain, and tearing, and could even accelerate the progression of myopia. This brief review of paediatric cycloplegic refraction, informed by years of clinical input and a review of relevant literature, is aimed at pointing out some critical steps, methods, and cycloplegic agents essential for carrying out the procedure to meet the growing need for accurate refraction outcomes and provision of appropriate correction, especially among children. It also showcases some guidelines for dispensing prescriptions for spectacles in the setting of paediatric cycloplegic refraction. This review may help to highlight the need for evidence-based paediatric eye care practice, interdisciplinary collaboration among eye care professionals, and supporting research and the development of new cycloplegic agents and protocols.

KEYWORDS: cycloplegic refraction, accommodation, esotropia, cyclopentolate, pseudomyopia.

INTRODUCTION

Refraction is a clinical procedure to assess refractive errors. It is comprised of three components: objective (requires patient cooperation but no input), subjective (requires patient input), and cycloplegic refraction (can be "with" or "without" patient input but the eye is influenced by a pharmacological agent). The relevance of cycloplegic refraction in paediatric ocular assessment cannot be over-emphasised as it is an essential component of comprehensive paediatric eye care, ensuring the thorough assessment of refractive error and appropriate management. In addition, data generated through cycloplegic refraction can be invaluable in understanding paediatric refractive error trends and informing public health initiatives. Young individuals often experience difficulty in realizing their full potential without effective eyesight as most learning and daily interaction are vision-dependent.[1,2] This is evidenced by the extensive efforts made in various societies to support individuals with vision impairment, with adaptation resources that enable their independent navigation and daily functioning.[1] Hence, effective measurement, correction and documentation of refractive errors for reference purposes are imperative.

Cycloplegic refraction is the process by which refractive errors are assessed using a cycloplegic agent or agents. A cycloplegic agent is a type of ocular

medication that temporarily paralyzes the ciliary muscle of the eye, resulting in a loss of accommodation. Children and younger adults are able to overcome some of the challenges posed by uncorrected refractive errors due to their robust accommodative abilities. Accommodation is the ability of the eye to vary its focal length to bring focus or clarity to objects at varying distances. The younger the child, the higher the accommodative ability (quantified as the amplitude of accommodation), and the more difficult it is to neutralize this ability. This accommodative ability decreases with age, until the late 30s, when the decrease becomes apparent and near work becomes increasingly difficult: this condition is called presbyopia.

The robust accommodative ability of children can significantly affect the accuracy of the assessment of their refractive error. This can be compounded by difficulty in obtaining effective subjective responses from children, resulting in the inaccurate dispensing of prescriptions for spectacles. This might contribute to strabismus (squint), amblyopia (lazy eyes), non-optimal vision, asthenopic symptoms like eyestrain, and tearing, and could even accelerate the progression of myopia.[3]

Cycloplegic agents such as homatropine and cyclopentolate can be used to temporarily neutralize accommodation before refraction (objectively and subjectively) to obtain accurate refractive outcomes in children.[3]

INDICATIONS FOR CYCLOPLEGIC REFRACTION

Cycloplegic refraction is the gold standard for accurate assessment of refractive error in children and adults with active accommodation. It helps prevent overestimation of myopia or underestimation of hyperopia, particularly in children, since their accommodative amplitude is quite high and they often respond inconsistently during normal subjective refraction. In addition, it can be valuable in the following conditions:

- When there is an insignificant or unreliable outcome in subjective refraction
- When there is suspected latent hyperopia or unexplained asthenopic symptoms
- Determination of the full hyperopic correction in the management of manifest childhood esotropia
- Management of accommodative spasm or accommodative fatigue
- Strabismus and anisometropia
- Diagnosis as well as proper management of uncompensated esophoria and suspected pseudomyopia[3]
- Pharmacological occlusion therapy in amblyopia management
- Assessment of eyestrain in adult hyperopia
- Unmasking the reason behind poor stereoscopic acuity[4]
- Screening when there is a family history of high refractive errors[3]
- Evaluation of suspected malingerers or hysterics
- Accurate determination of refractive error before laser refractive surgery[4]
- Examination of handicapped or mentally disabled patients due to the likelihood of their uncooperative responses during subjective refraction.[5]

LIMITATIONS OF CYCLOPLEGIC REFRACTION

Cycloplegic refraction is subject to the legislative stance of a jurisdiction regarding the use of ocular pharmacological agents for eye examination. In some countries, the use of ocular diagnostic agents is restricted to medical doctors alone, hence other eye care practitioners such as optometrists and ophthalmic nurses are excluded. In this case, crude methods of relaxing accommodation during refraction (such as the fogging lens method) may be adopted, but these practices are not as effective as the use of a cycloplegic agent.[3]

Cycloplegic refraction is used selectively to help determine the refractive power of the eye. A recent study to determine the age up to which cycloplegia is required for accurate refraction results indicated that it should be performed up to the age of 20 years and possibly 35 years depending on the patient's complaint.[4,5]

The cycloplegic outcome can be inconsistent and incomplete due to the fact that accommodative function is not easily suppressed, coupled with the ocular aberrations accompanying mydriasis. Thus, post-cycloplegic or repeated refractions are often required to attain accurate results, especially in children found to have significant hyperopia.[5]

Spectacles may not be prescribed based on the cycloplegic findings alone because visual acuity may be reduced due to a likely change in the refractive error when the eye returns to its normal state of accommodative tonus.[6] This may also be related to overcorrection (in hyperopia) or under-correction (in myopia) during cycloplegic refraction. Hence, the final prescription should consider the eye's dynamic behaviour and adaptability.

Cycloplegic refraction is inconvenient for the patient because the loss of accommodation and mydriasis do not reverse easily, but last for several hours to days after examination (depending on the cycloplegic agent used) and may temporarily hamper the patient's routine activities. Moreover, the use of miotics to counter the effects of cycloplegia is no longer advocated because the resultant miosis and ciliary spasm can cause significant discomfort including nausea, headache, a burning or stinging sensation, and induced pseudomyopia.[7] Besides, they do not reverse the cycloplegic or mydriatic effect effectively due to pharmacological opposition, dose difference, differences in duration of action, and differences in tissue penetration between the miotic and cycloplegic agents as well as individual variability.

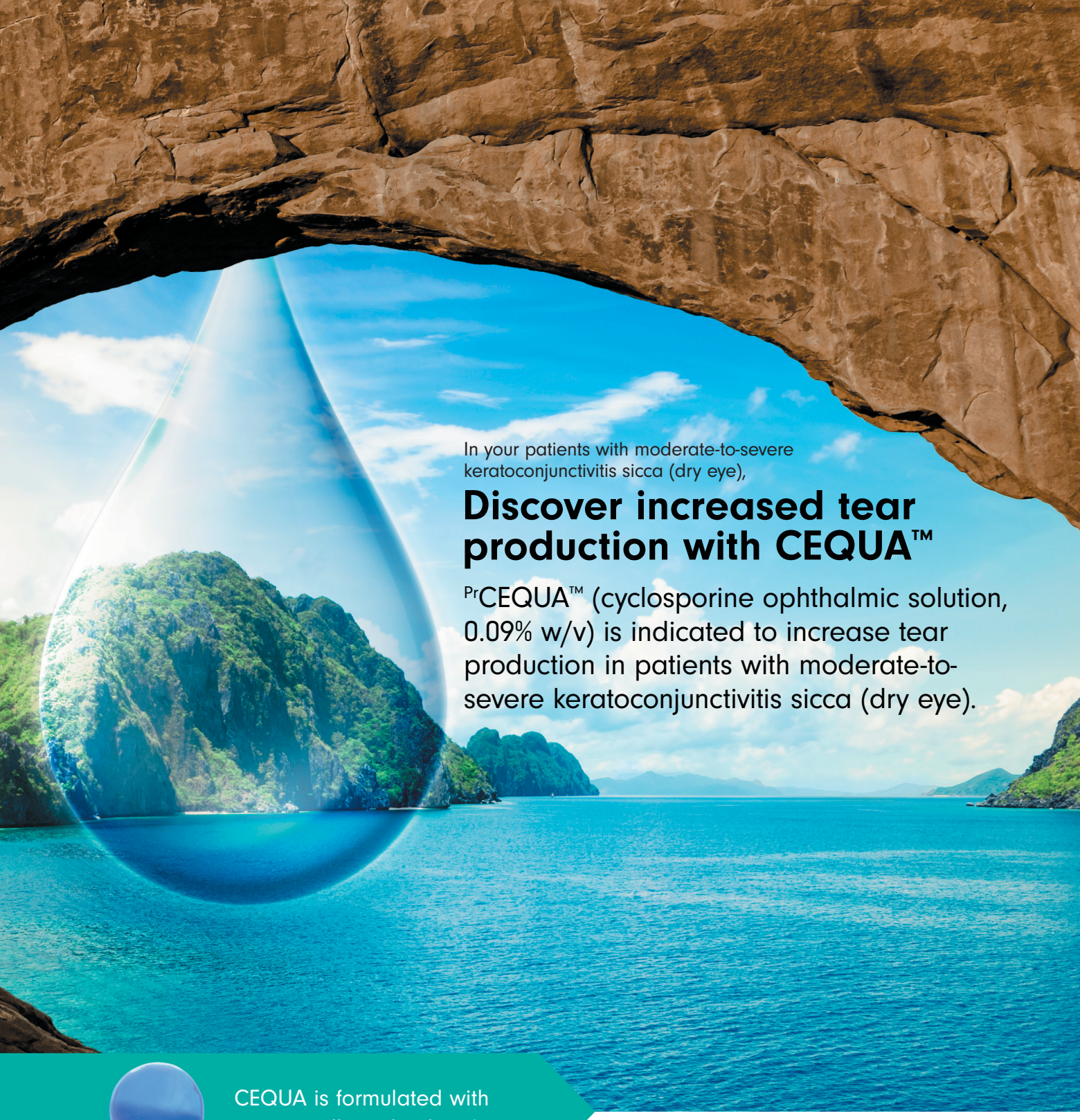
Furthermore, all cycloplegic agents have potentially significant local and systemic side effects, especially in children. Some can cause decreased saliva production resulting in dry mouth and throat, while others can cause an increase in heart rate. Flushing of the skin can occur as a result of vasodilation. The central nervous system can be affected, leading to an increase in body temperature, confusion, restlessness, hallucination, or even death when given in higher doses, particularly with atropine. However, some are safe with rare central nervous system disturbances. Besides, to minimize excess systemic absorption that might trigger adverse reactions, gentle pressure should be applied over the nasolacrimal sac or alternatively the eyes can be tightly closed for about 3-5 minutes after drop instillation. The resulting pupillary dilation can result in blurred vision and photophobia. These agents can also bring about an increased accommodative convergence/accommodation ratio (AC/A) with accompanying difficulty in performing near tasks.[4,7] Other side effects include temporary blurry vision (usually at near, but potentially at distance depending upon refractive error), occasional double vision, photophobia, redness or eye irritation, and occasional headache.

Lastly, due to the long time required for cycloplegic drops to bring about their effect, longer or additional appointment times may be required, which may inconvenience parents, their children and the eye care practitioner.

CYCLOPLEGIC AGENTS

Cycloplegic drugs are collectively called parasympatholytic or anticholinergic agents because they reduce or oppose the activity of the parasympathetic nervous system through their anticholinergic action. This means that they prevent the neurotransmitter acetylcholine from acting as a neurotransmitter at muscarinic receptors. When these agents are instilled in the eyes, this action causes mydriasis and cycloplegia. Commonly used cycloplegic agents include cyclopentolate, tropicamide, atropine, scopolamine, and homatropine.

Cyclopentolate is available in solutions of 0.5%, 1%, and 2%,with 1% (0.5% for children below 1 year of age) accepted as the gold standard for cycloplegic refraction.[3] It is used 1 drop every 5-10 minutes in 2 doses. It is most tolerable, with a relatively rapid onset of action and a short duration of effect; hence, it is suitable for most patients. Cycloplegia occurs within less than 1 hour (between 30-60 minutes) with a recovery period of less than a day, but it has occasional adverse effects, especially in children, who may experience a marked transient stinging sensation, behavioural changes, visual hallucination, slurred speech, and incoherence. Allergic reactions with symptom such as eyelid oedema, conjunctivitis, and tearing may also occur. Refraction must be carried out within 1 hour of drug instillation due to its rapid onset and the short duration of its cycloplegic effect. On the other hand, in the case of closed eyes (uncooperative children), the use of cyclopentolate spray or placing one drop on a closed eyelid had a success rate for complete cycloplegia that was equivalent to placing one drop directly on the cul-de-sac; this can be an option because it is less stressful than drop application in these children.[8,9] This approach can also be used with other cycloplegic agents. However, the resulting cycloplegia is only partially effective in children with a dark iris. When used for cycloplegic refraction, a drug correction of 0.75D is applied to the retinoscopic value as tonus allowance.[10,11] This is an estimated factor that accounts for residual accommodation (or the potential impact of tonus



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on retinoscopic measurements) as cyclopentolate may not completely neutralize accommodation, especially in children, thereby ensuring a more accurate prescription.

Tropicamide is available in concentrations of 0.5% and 1%, and at 0.25% in combination with 1% hydroxyamphetamine hydrobromide (Paremyd). A concentration of 0.5% can be used in infants up to 3 months of age. However, 1% is used most often in clinical settings for an enhanced cycloplegic effect. It is applied in 2-3 doses of 1 drop every 5 minutes. Its cycloplegic onset occurs within 25-30 minutes and this effect lasts for 30 minutes. Tropicamide is an effective, fast-acting mydriatic agent with weak cycloplegic action, a shorter duration of action and complete recovery within approximately 5-6 hours. Therefore, it is most useful for ophthalmoscopy and in older children because refraction has to be performed within a short time frame. A topical anaesthetic (0.5% proparacaine) may be instilled initially to minimise reflex tearing that may arise as a result of the stinging sensation produced by the drug. This helps maintain an adequate concentration of the drug in the eye, which in turn enables its adequate absorption and effectiveness, and reduces the stinging sensation that may arise in subsequent drops. This approach can also be applied in the administration of other cycloplegic agents, especially in infants. Tropicamide is safe with rare disturbances of the central nervous system. However, it can be used as an alternative to cyclopentolate in children with known sensitivity, central nervous system disorders, Down syndrome, or a dark iris because of efficient iris penetration, as well as in nonstrabismic children 3-16 years irrespective of their refractive error status.[3,12]

Atropine is available in concentrations of 0.5%, 1% and 3%, as both topical ophthalmic drops and ointment. A 1% solution is used most often in clinical settings. It is applied in a dose of 1 drop 2 times daily for 1-2 days to achieve a full cycloplegic effect. Full mydriasis occurs within 20-30 minutes and a cycloplegic effect occurs at 1-3 hours. A full cycloplegic effect occurs within days. Atropine is a strong, effective, slow-onset and long-acting cycloplegic agent. Its effects last for several days to weeks and this can be unpleasant and inconvenient. Caution must be applied in its use to avoid adverse side effects such as skin flushing, fever, dry mouth, confusion, hallucination, rapid and irregular pulse, or restlessness resulting from systemic absorption which can be fatal as a result of an idiosyncratic response after instillation of 1 or 2 drops in each eye or from over-dosage after multiple instillations of the drug.[13] Parents and caregivers should be well-informed of the early signs of the side effects so that they can stop administration and hopefully avoid side effects. When adverse effects occur, immediate medical attention is required by administration of up to 2 mg of physostigmine salicyclate at 0.02-0.03 mg/kg, intravenously or intramuscularly. This is repeated at 30-minute intervals and after 1-2 hours as required. When cyclopentolate is ineffective in children with a very darkly pigmented iris, atropine may be used to achieve the desired effect. When used for cycloplegic refraction, a 1.00D drug correction is applied to the retinoscopic value as tonus allowance.[10] This is an estimated factor that accounts for residual accommodation (or potential impact of tonus on retinoscopic

measurements) as atropine may not completely neutralize accommodation, especially in children; thereby ensuring a more accurate prescription.

Scopolamine hydrobromide is available in concentrations of 0.25% and 0.50% as both topical ophthalmic drops and ointments. However, 0.25% solution is used most often in clinical settings. It is applied as 1 drop every 5-15 minutes in 2-3 doses before refraction to achieve a full cycloplegic effect. The onset of its cycloplegic effect occurs within about 30-40 minutes and the maximum effect is seen within 1-2 hours. It is an effective, fast-acting cycloplegic agent, with a duration of action of up to 3-5 days. However, it has a tendency to cause dizziness and disorientation, mainly in older individuals, and must be used with caution in this population.[7]

Homatropine hydrobromide is available in concentrations of 2% and 5%. It is applied as 1 drop every 5-10 minutes in 2 doses before refraction. It is a fast-acting and effective cycloplegic agent, with cycloplegic onset within 20-30 minutes and a maximal cycloplegic effect within 40-60 minutes; it is effective for 2-3 hours and complete recovery takes 1-2 days. This shorter duration of cycloplegia, more rapid recovery, and the lower risk of side effects, gives it an advantage over atropine and scopolamine.[11] Homatropine instillation is rarely associated with side effects. When used for cycloplegic refraction, a drug correction of 0.50D is applied to the retinoscopic value as tonus allowance.[10] This is an estimated factor that accounts for residual accommodation (or the potential impact of tonus on retinoscopic measurements) as homatropine may not completely neutralize accommodation, especially in children, thereby ensuring a more accurate prescription.

STEPS FOR CYCLOPLEGIC REFRACTION IN CHILDREN

The following principles may be adhered to when performing cycloplegic refraction for maximum cooperation and effectiveness:

1. Explain the procedure to the child and their parents for their consent.
2. Measure the child's entering uncorrected visual acuity with a Snellen chart or equivalent.
3. Carry out the manifest (dry) refraction to determine the manifest refractive error.
4. Instil cycloplegic eye drops (usually cyclopentolate) into both eyes. Children often do not like anything touching their eyes, and cycloplegic eye drops are not an exception. They can cause a stinging or burning sensation in the eyes which can make a child uncomfortable. Depending on the child's age and disposition, an anaesthetic eye drop can be instilled before the cycloplegic eye drop, to reduce this sensation.
5. Let the patient wait for 30-45 minutes (with cyclopentolate) for the drop to take effect. When this is not possible, mainly in children with a dark iris, repeat the drop instillation, always observing temporary punctal closure for about 2 minutes and wiping away any excess to reduce systemic absorption.
6. When the full effect of the drug is achieved, which usually coincides with the time when the pupil is no longer reactive to light, carry out retinoscopy or autorefraction to estimate the refractive error.
7. Record and interpret the results, comparing them with the first manifest (dry) refraction to draw a tentative diagnosis.
8. Advise the parents that their child will experience blurry vision and photophobia for up to several hours (or longer, depending upon the agent used) due to cycloplegia and mydriasis.
9. Schedule a follow-up appointment several days after the effect of the cycloplegic agent used would be expected to have worn off to perform another manifest (dry) refraction, given that the patient's cycloplegic refraction may not be the same as the manifest (dry) refraction.
10. Document and interpret all of the results to draw a final diagnosis and to decide on the appropriate management. Communicate the results to the parents or guardians and provide appropriate recommendations.

Of course, there may be variations in this procedure depending on the child's needs and the eye-care professional's preference.

SOME GUIDELINES FOR CYCLOPLEGIC PRESCRIPTION IN SCHOOL-AGE CHILDREN

As the eye grows from birth, the axial length increases while the cornea and lens flatten, ideally leading to emmetropization in adulthood.[14] When correcting refractive errors in children, the goal should be tailored towards achieving the best possible visual acuity and a healthy balance between accommodation and convergence to support optimal vision and comfort. Children with moderate and high hyperopia are more likely to remain significantly hyperopic throughout childhood and are prone to developing refractive and strabismic amblyopia. With early partial optical correction, these risks can be ameliorated.[14]

In prescribing for hyperopic children, manifest (dry) and cycloplegic retinoscopy, dry and wet subjective refraction, binocular assessment, the accommodative convergence/accommodation (AC/A) ratio, age, degree of hyperopia, and visual acuity should be considered. This is aimed at reducing accommodative demand, facilitating normal binocularity, improving adherence to treatment, and providing clear and comfortable vision.[6] Children with mild (low) hyperopia may require no spectacle correction except when the refractive error is accompanied by strabismus (tropia), amblyopia, or other significant vision problems.[14] However, in some patients (pending their age and refractive status), spectacle correction or corresponding corrective contact lens should be given to children with moderate to high hyperopia, and any accompanying significant astigmatism (i.e., a level of astigmatism that can cause noticeable vision problems and affect activities of daily life, e.g., ±0.75DC or more) should be simultaneously fully corrected. Individuals with amblyopia should be engaged in occlusion therapy or penalisation.

Full cycloplegic refractive correction should be given to children with hyperopia associated with accommodative esotropia.[4,14] After adaptation to the correction, a reduced correction may be considered if it can give good binocularity, as with full correction, based on the degree of deviation in both distance and near vision. However, if there is good adaptation to the full correction, no adjustment would be considered. Accommodative esotropes may make it possible to discontinue the use of glasses as a result of increased fusional divergence amplitudes, the loss of hyperopia, or a reduction in synkinesis between accommodation and convergence.[14] However, in some school-age children, full cycloplegic correction may result in blurry distant vision due to their inability to fully relax accommodation. This can be assessed by comparing the spherical power of the manifest (dry) refraction and that of the cycloplegic refraction to note any significant difference (e.g., >0.50DS) between the two or by checking for residual accommodation using the fogging lens method. In the comparison of the difference in spherical power, if the spherical power in the cycloplegic refraction is more hyperopic (less minus or more plus) than the manifest refraction, this would indicate incomplete relaxation of accommodation or the presence of residual accommodation which may cause blurry distance vision if significant. The cylindrical powers and axis should also be checked to ensure they are not the source of the blurry distance vision. The fogging lens method is carried out as follows:

- Perform cycloplegic refraction to note the child's error and visual acuity
- Add fogging lenses bilaterally (+1.00 to +2.00 DS) to the trial lens over the cycloplegic result; this will blur the child's near vision
- Ask the child to look at a distance chart (Snellen chart or picture chart depending on the child's age)
- Check for improvement in visual acuity. If the child's vision clears or improves with the fogging lenses, this indicates residual accommodation.
- Gradually reduce the power of the fogging lenses (e.g., -0.25DS steps), while monitoring the child's distance vision.
- Note the endpoint. This is the point at which the child's distance visual acuity starts to blur again. This indicates the maximum relaxation of accommodation.
- Calculate the amount of residual accommodation by subtracting the endpoint from the initial fogging power.
- For instance, if +1.75DS fogging lenses clear the distance vision, and the endpoint is reached at +1.00DS, the residual accommodation is +0.75D

In addition, full wet refraction is adjusted (slightly reduced) by the amount of the residual accommodation to ease adaptation. If this is not achieved with adjustment of the residual accommodation, the principle of bilateral equalize

plus spherical power reduction (+0.25 to +0.50DS) or the addition of minus spherical power (-0.25DS to -0.50DS) is applied to ensure that symmetry between eyes is maintained, thereby ensuring optimal visual acuity and comfort. If astigmatic correction is involved, the principles of balance cylindrical power, axis and binocular alignment monitoring should be considered to ensure proper alignment and balanced vision. On the other hand, if there is no associated esotropia, a slight reduction in the correction power may improve spectacle acceptance and tolerance.

In pseudomyopia, which results from excessive accommodation or ciliary spasm, there is blurry distance vision following extensive near work. Retinoscopic refraction gives hyperopia, while the patient prefers minus correction in subjective refraction. Pseudomyopia is occasionally associated with high exophoria. This occurs as a mechanism of sustaining fusion through accommodative convergence.[14] Full cycloplegic correction (plus lens power) for full-time wear should be given to relax the accommodation or the associated latent asthenopic symptoms in children and for near vision in adults. This can be reduced or completely eliminated if/when the symptoms are completely resolved.

In myopia, asthenopic symptoms are uncommon; however, if present, they may be a result of associated astigmatism, anisometropia, pseudomyopia, or accommodative or vergence dysfunction.[14] Full cycloplegic correction should be considered if there is significant accommodative stress after correction of the factors associated with the asthenopia so as to overcome the asthenopic symptoms. In myopic children with associated high exophoria, full-time wear of the full myopia correction is necessary.[14]

Astigmatism may be associated with hyperopia or myopia. However, cycloplegia has an insignificant impact on the cylindrical component of the refractive error, because astigmatism is associated with corneal irregularities or lens shape, not accommodation. This means that it has no effect on corneal curvature or lenticular shape, and instead affects the ciliary muscle that controls accommodation. It primarily affects the spherical components by reducing the eye's accommodative ability and revealing the true spherical error.

In children with moderate anisometropia (1.00-2.00D) and high anisometropia (>2.00D-2.50D), full cycloplegic refractive difference between two eyes should be given initially in spite of age and the magnitude of strabismus, provided binocular vision is present to maintain binocular alignment and prevent amblyopia.[14] Gradually, a step-by-step approach is applied to reduce the prescription equally over time (e.g., every 2-3 months) in steps of 0.25D or 050D to maintain the same degree of anisometropia, while monitoring adaptation so as to maintain optimal vision. However, initially, less than the full anisometropic prescription may be instituted in some patients, particularly adults, to prevent diplopia and ensure acceptability, comfort and tolerance.

CONCLUSION

Cycloplegic refraction is necessary to meet the growing need for the accurate assessment of refractive error and the provision of appropriate correction, especially among children.[3] This will help to protect visual health (via safety measures to safeguard and preserve the health of the eyes and visual system) and the well-being of the young generation. Vision correction through cycloplegic refraction can ultimately improve academic performance and the overall quality of life for many children. Cycloplegic refraction facilitates early intervention for vision problems, thereby reducing the risk of complications. It is important in pharmacological occlusion and as a penalisation tool in the management and prevention of amblyopia.[6] The mydriasis during cycloplegic refraction also helps the clinician perform a thorough internal ocular examination. It is also useful in research and clinical trials to assess refractive errors and evaluate new treatments.

Urgent advocacy is needed for legislative changes that will empower qualified eye care professionals to use cycloplegic agents, especially in countries where they are currently prohibited.[3] This will help promote more comprehensive and higher quality eye health examination outcomes in children. Advocacy is also needed to create an evidence-based paediatric eye care practice, interdisciplinary collaboration among eye care professionals, and to support research and the development of new cycloplegic agents and protocols.[5]

DISCLOSURES

CONTRIBUTORS: All authors contributed to the conception or design of the work, the acquisition, analysis, or interpretation of the data. All authors were involved in drafting and commenting on the paper and have approved the final version.

FUNDING: This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

COMPETING INTERESTS: All authors declare no conflict of interest.

ETHICAL APPROVAL: Not required for this article type.

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