Review Article

Pediatric cycloplegic refraction

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ABSTRACT

Background: Cycloplegic refraction is an essential part of the pediatric ophthalmic assessment and is the cornerstone of strabismus evaluation. This narrative review aimed to ascertain the current scope of practice for cycloplegic refraction in the pediatric population.

Methods: An extensive literature review was conducted using ScienceDirect, PubMed/MEDLINE, Scopus, and Google Scholar databases using the following search terms: cyclopentolate, tropicamide, pediatric cycloplegia, atropine, homatropine, manual retinoscope, handheld autorefractometer, spherical errors, and no spherical errors of refraction in articles published from January 2000 to December 2022. Relevant retrieved references and practical points concerning pediatric cycloplegic refraction were summarized.

Results: Atropine has the most potent cycloplegic effect and is best used in cases of severe accommodative esotropia. Because of the unfavorable side effects and risks associated with atropine, cyclopentolate has been found to provide quite effective cycloplegia, even for moderate to severe hyperopia, and has become the standard agent for traditional pediatric cycloplegic exams. Tropicamide has also been shown to provide adequate cycloplegia while being less toxic and causing fewer side effects. Tropicamide has the fewest side effects and toxicity of all agents, while atropine has the most. Cyclopentolate is an exceptionally safe cycloplegic agent. To detect spherical and non-spherical refractive errors, refraction can be performed using a handheld autorefractometer or a manual retinoscope, as well as under general anesthesia in some cases. The optimal time to wear eyeglasses to maintain binocular vision and avoid amblyopia is also considered.

Conclusions: Accommodative power in children is at its maximum, and this interferes with reliable assessment of refraction. Therefore, the use of cycloplegic refraction is mandatory during childhood to obtain actual refraction, which is considered the cornerstone for eyeglass prescription. Knowledge of the various cycloplegic agents used in childhood refraction is important for ophthalmologists and optometrists to obtain safe and effective cycloplegia. High refractive errors, as well as the presence of anisometropia or squint, necessitate the use of eyeglasses as early as childhood to maintain binocularity and depth perception.

KEYWORDS

pediatrics, ophthalmologist, optometrist, cycloplegic, mydriatic, anticholinergic syndrome, squint, homatropine hydrobromide, cyclogyl, tropicacyl, retinoscopies, eyeglasses, spectacles

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INTRODUCTION

The primary causes of ocular morbidity in children are refractive errors and strabismus, and effective refractive correction is essential for achieving ideal vision and binocularity. Cycloplegic refraction is an essential part of the pediatric ophthalmic assessment [1] and is the cornerstone of strabismus evaluation [2]. The eye adjusts its optical power during accommodation in order to focus on objects at various distances. Children have a substantially stronger accommodative reflex than adults. The ability of the human eye to shift its focus from far to near declines with age [3, 4].

Cycloplegia is the condition in which the ciliary muscles are inhibited by pharmacological agents. Inadequate cycloplegia is the presence of residual accommodation following the administration of cycloplegic drugs, and it can be identified via dynamic retinoscopy and near acuity testing [5]. The timing of the onset and resolution of cycloplegia, as well as its depth, represent the primary differences in the various cycloplegics used in clinical practice [6]. When the maximum effect of cycloplegia has been reached, overmedication increases the likelihood of systemic absorption and amplifies the adverse effects. It is challenging in pediatric ophthalmology to administer the appropriate cycloplegic drug at an appropriate dosage and timing for different age groups with refractive errors with or without strabismus [6].

This narrative review aimed to ascertain the current scope of practice for cycloplegic refraction in the pediatric population.

CYCLOPLEGIC AGENTS

Cycloplegics inhibit accommodation through pharmacological paralysis of the ciliary muscles [7, 8]. When the ciliary muscles relax, the eye relaxes owing to thinning of the lens, which aids in focusing on distance [9]. Cycloplegic drugs block the muscarinic effect of acetylcholine on ciliary muscle receptors, preventing stimulation of the ciliary muscles and sphincter of the iris [10]. Thus, cycloplegics are referred to as antimuscarinics, anticholinergics, or parasympatholytic agents [11, 12]. The efficacies of these drugs have been reported in many studies [13-15]. The cycloplegic drugs include atropine, homatropine, cyclopentolate, and tropicamide [16].

Atropine sulfate

Atropine is one of the most potent drugs available for cycloplegia and mydriasis through paralysis of the ciliary muscle and sphincter pupillae [16]. It is an anticholinergic drug that acts on muscarinic receptors and is formulated as topical drops and ointment in concentrations of 0.01%, 0.5%, 1%, and 3% [16]. The protocol for refraction is a twice a day or once-daily morning dose of 1% atropine applied for three days [17, 18].

Atropine is also indicated in some inflammatory conditions to prevent synechiae formation through pupillary dilatation, in amblyopia management by penalization, in ciliary block glaucoma, postoperatively in some intraocular surgeries, in the Tensilon test to prevent vagal response, and to treat accommodation spasms [16]. It is widely accepted that atropine 0.01% can control the progression of myopia [18].

Homatropine hydrobromide

Homatropine 2% is an anticholinergic drug that prevents the muscarinic action of acetylcholine, leading to cycloplegia and mydriasis [16]. It is also indicated in some ocular inflammatory conditions. The protocol for refraction is one drop every 10 min for a total of six doses [16]. Refraction can be performed 90 min after instillation of the first drop, with the effect lasting up to 72 h. For the tonus allowance, 0.5 D is subtracted from the final refraction value [16, 17].

Cyclopentolate hydrochloride

Cyclopentolate is also an anticholinergic drug available in ophthalmic solutions of 0.5%, 1%, and 2% concentrations and has a faster onset and shorter duration of action [16]. The protocol for refraction is one drop applied then a repeated drop after 5 min. Its effect occurs within 30 to 45 min of instillation and lasts for 6 to 18 h. As a tonus allowance, 0.75 D is subtracted from the final refraction value [16, 18].

Tropicamide

Tropicamide is the most commonly used mydriatic drug because of its low side effect profile, powerful mydriatic effect, and rapid onset of action. It is available in two concentrations, 0.5% and 1%; 1% produces cycloplegia, and 0.5% produces pupillary dilatation with minor cycloplegia [16]. Owing to less dilatation alone in preterm infants, it can be supplemented with a combination of 2.5% or 5% phenylephrine [16, 19, 20].

Side effects of cycloplegics

Cycloplegics should be avoided in children with narrow anterior chamber angles and in those with a previous allergy or adverse reaction to any drug ingredient [21]. Local side effects include stinging sensation, injected bulbar conjunctiva, elevated intraocular pressure, blurred vision, and photophobia [12, 22]. Systemic side effects include skin rash, tachycardia, dry mouth and skin, behavioral disturbances, and psychotic reactions [23].

Side effects of atropine include blurring of vision for 10 to 14 days due to persistent pupillary mydriasis. There is no antidote for atropine, and systemic medications that contain atropine derivatives can induce prolonged cycloplegia of the pupil [24, 25]. Other local side effects include dryness of the periocular skin, crusting of the lid margins, and allergic reactions of the lids and conjunctivae [25].

Systemic side effects of atropine include irritability, tachycardia, skin and mouth dryness, hyperpyrexia, abdominal distension, flushing, skin rashes, and rarely, progressive respiratory depression [25, 26]. It should be avoided in children if possible because it can be systemically absorbed through the lacrimal sac. To avoid systemic absorption, compression of the lacrimal sac for 1 min after topical administration is advised [25].

Homatropine rarely has side effects, such as visual disturbances, psychosis, disorientation, hallucinations, and incoherent speech [27]. Cyclopentolate has few side effects, such as blurred vision and lacrimation. Systemic manifestations include restlessness, speech disturbance, disorientation, ataxia, and hallucinations [28]. Tropicamide causes a local stinging sensation, and systemic absorption may cause disorientation and hypersensitivity reactions in children [29].

Use of cycloplegics

Table 1 provides a summary of protocols for use of cycloplegics in children.

OBJECTIVE REFRACTION

Retinoscopy

Cycloplegic retinoscopy is the reference standard for measuring refractive errors in the pediatric age group, as objective refractive errors can be obtained by completely relaxing accommodation using this method [40-42]. Retinoscopy has some limitations because it requires advanced clinical training and is mostly user-dependent [43-45]. The results of retinoscopy provide information about risk factors for ocular morbidities, such as glaucoma and retinal detachment in myopic patients [46]. Patients with severe hyperopia may develop amblyopia and accommodative esotropia [47]. Retinoscopy with cycloplegia is referred to as wet retinoscopy [16].

Table 1. Protocol for cycloplegia [16-18, 30-39].

Protocol for Cycloplegia		
I. Cycloplegic refraction should be performed on all children under the age of 12 years who have refractive error or strabismus during the initial visit.		
II. Choice of cycloplegic agent:		
Age range	**Category**	**Drug of choice**
< 2 years	All children	Atropine (1%)
2 – 5 years	With esotropia Without esotropia	Atropine (1%) Cyclopentolate (l%) and tropicamide (1%) (CT)
5 – 8 years	With esotropia Without esotropia Myopia Hyperopia	CT CT Tropicamide (1%) CT
8 – 12 years	With esotropia Without esotropia	CT Tropicamide (1%)
III. Dosage of cycloplegic drugs: • Atropine sulfate (1%): To be instilled once daily or twice a day for 3 days. • Homatropine hydrobromide (2%): To be instilled 1 drop every 10 min for a total of six doses. • CT: 3 drops instilled at intervals of 15 min. • Tropicamide (1%): 3 drops instilled at intervals of 10 min.		
IV. Duration of cycloplegia: • Atropine sulfate (1%): After 3 daily instillations, has long duration of action (10 – 15 days). • Homatropine hydrobromide (2%): After 90 min of first instillation, provides cycloplegia up to 72 h. • CT: After 60 min of first instillation, provides cycloplegia for 12 – 24 h. • Tropicamide (1%): Within 30 – 45 min of first instillation, provides cycloplegia for 4 – 10 h.		

Retinoscopy is conducted in a dimly lit environment. The patient is situated 1 m from the examiner. The retinoscope light is shone into the patient's eye, and the patient is instructed to gaze at it [16]. In dry retinoscopy, the patient is asked to focus on a distant object to allow the accommodation to relax. The red reflex is observed in the pupillary area through a hole in the retinoscope mirror. In examining the retinoscopic reflex, the retinoscope is moved in the horizontal and vertical meridians [48].

Depending on the distance and mirror used, significant conclusions can be drawn from the retinoscopic reflex movement. Based on the red reflex movement for the 1 m setting of the plane mirror [16], no movement implies a 1 D myopia [16]; a movement in the retinoscope's direction suggests emmetropia, hypermetropia, or myopia of less than 1 D [16]; and a movement opposite the retinoscope's direction indicates myopia greater than 1 D [16].

Autorefractometers

Cycloplegic autorefraction is a technique commonly used in research studies and clinical practice to acquire objective refraction measurements. It is considered reliable and accurate for pediatric patients [49]. Compared to subjective refraction, it is quicker and relies less on the child's cooperation. Cycloplegic autorefraction is the reference standard in epidemiological research involving young children [50].

Some challenges in using autorefractors in children include keeping the child in the proper position, ensuring that the head is aligned, and sustaining visual focus on a target [51]. When these difficulties prevent a proper pediatric evaluation, photoscreening may be a preferable option [52, 53].

A commonly used instrument is the autorefractor, which relies on classical measurement principles to determine refractive error [54, 55]. Technological advancements have created tools that use wavefront analysis to measure the refractive state of the human eye [56]. One such device is the Complete Ophthalmic Analysis System, which uses several data points in the pupil to calculate refraction from Zernike polynomials [57-59].

Photoscreeners and hand-held autorefractometers

Plusoptix: This is a handheld photorefractor, useful for young and uncooperative patients, to measure refractive errors without cycloplegia. Within 1 s and at a distance of 1 m, the device measures both eyes simultaneously [60]. The device uses lights and sounds for fixation targets and measures the interpupillary distance, ocular alignment, and pupil size. The device has a range from - 7.0 to + 5.0 D for both cylindrical and spherical measurements [52, 60, 61]. Because of the underestimation of hyperopic refractive errors, Plusoptix was reported to be more accurate in myopic, astigmatic, and anisometropic eyes than in hyperopic eyes [62]. Compared with cycloplegic retinoscopy, Plusoptix was found to be very useful, particularly in determining the cylinder power and axis [63].

Spot Vision Screener: This is a handheld photorefractor that provides measurements of both eyes simultaneously from a distance of 1 m within 2 s without cycloplegia. It has a spherical measurement range of - 7.50 to + 7.50 D and cylindrical measurement range of - 3.00 to + 3.00 D [64].

Retinomax K-plus Screen: This is a handheld portable autorefraction keratometer. Monocular refractive errors are measured using the device at a distance of 5 cm. It uses a fogging mechanism to control accommodation [65]. Additionally, the device has a fast mode that takes measurements in 1 s while playing a tune to attract the child's attention. The device can perform spherical measurements in the range of - 20.0 to + 23.0 D and cylindrical measurements in the range of 0 to ± 12 D [66].

Refraction under general anesthesia

There are four stages of general anesthesia (GA): analgesia, delirium, surgical anesthesia, and respiratory arrest [67, 68]. During surgical anesthesia, gradual loss of reflexes and muscle tone is observed. Theoretically, a loss in ciliary muscle tone and paralysis of accommodation occur at this stage [68]. GA affects the eye position in strabismus [69] and decreases accommodative tonus but does not create complete accommodation paralysis [70]. Thus, when precise refraction measurements are required, cycloplegic drops should be used before GA [71]. When measuring under GA, the lower and upper eyelids are opened without applying pressure to the globe, and a handheld autorefractor such as Retinomax K-plus is used [71].

WHEN TO PRESCRIBE EYEGLASSES?

Before prescribing eyeglasses, it is important to consider factors such as age-related visual demands, significant accommodating aspects, amblyopia risk, age-related emmetropization, and related problems such as strabismus [72]. Neonates are normally hypermetropic (< 4 D) with little astigmatism (< 2 D). With increasing age, astigmatism and hypermetropia decrease, and emmetropization is completed by age 7 – 8 years [73].

Hypermetropia

Hypermetropia should be corrected earlier than myopia when a child's visual requirements are considered. Small degrees of hypermetropia in children can easily be addressed by strong accommodation. More than + 5 D of hypermetropia is challenging to correct and can lead to asthenopia [74]. Untreated hypermetropia also increases the risk of amblyopia and refractive accommodative esotropia. A mild under-correction can be equally applied to both eyes, if there is no esotropia, to allow for some accommodation [74]. The American Association for Pediatric Ophthalmology and Strabismus recommends that newborns with hyperopia of + 6 D or less do not need correction [75, 76].

Hypermetropia with esotropia

In cases of esotropia, full cycloplegic correction should be administered for even mild hypermetropia (> 1.5 D). Ages 2 – 4 years are the most common in which refractive accommodative esotropia manifests. A cover test is mandatory in all children with suspected hypermetropia prior to the instillation of cycloplegic eye drops, and atropine is recommended, at least for the first time, to ensure full appreciation of hypermetropia in these children [77].

Myopia

In newborns and toddlers, who have less demanding visual requirements, myopia ≤ – 4 D does not require correction. When children reach the age of 3 – 4 years and begin to spend substantial amounts of time looking at distant objects, prescription of eyeglasses for lesser degrees of myopia can be considered [78]. The goal is to prescribe the lowest negative power necessary for best-corrected visual acuity. In cases of intermittent exotropia, even the smallest myopic correction or overcorrection must be used to promote accommodation and convergence, and to eliminate exotropia [79].

Astigmatism

Even a refractive error of > 1.5 D must be corrected in children older than 2 years to prevent amblyopia, because astigmatism cannot be corrected by accommodation [78]. For older children, smaller cylinders can be prescribed even if their visual acuity is slightly reduced or if they have minor cylindrical power in addition to spherical power [73]. Guidelines for the prescription of eyeglasses in the pediatric age group, as proposed by the American Association for Pediatric Ophthalmology and Strabismus, are summarized in Table 2 [76].

Anisometropia

Compared to myopic anisometropia, cylinder anisometropia and hypermetropic anisometropia are more amblyogenic [79]. Occlusion therapy is necessary when amblyopia is already present [80]. In aphakic and pseudophakic patients, during the first few months, overcorrection by 2.00 – 3.00 D is recommended because the child is more involved in near activities. After 1 year, the near vision add can be reduced by 1.00 – 1.50 D [78].

This narrative review has addressed the significance of researching various cycloplegics used in pediatric patients during refractive error assessment. The evolution of instruments to detect refractive errors, from the retinoscope to automated machines, has been thoroughly researched. Excessive accommodation in children remains a significant barrier to detecting refractive error in the absence of cycloplegia. Future devices may be

Table 2. American Association for Pediatric Ophthalmology and Strabismus Guideline [76] for the prescription of eyeglasses for children aged up to 3 years

Condition	Diopters beyond which glasses should be considered		
	Age range (y): 0–1	Age range (y): 1–2	Age range (y): 2–3
ISOMETROPIA			
Myopia, D	≥ - 5.00	≥ - 4.00	≥ - 3.00
Hyperopia without esotropia, D	≥ + 6.00	≥ + 5.00	≥ + 4.50
Hyperopia with esotropia, D	≥ + 2.00	≥ + 2.00	≥ + 1.50
Astigmatism, D	≥ 3.00	≥ 2.50	≥ 2.00
ANISOMETROPIA			
Myopia, D	≥ - 4.00	≥ - 3.00	≥ - 3.00
Hyperopia, D	≥ + 2.50	≥ + 2.00	≥ + 1.50
Astigmatism, D	≥ 2.50	≥ 2.00	≥ 2.00

Abbreviations: y, years; D, diopters. Note: Isometropia, symmetric refractive error in both eyes; Anisometropia, asymmetric refractive error in both eyes.

used in refraction to overcome the problem of accommodation and to perform effective refraction without cycloplegia. However, we failed to include all the relevant studies. Future systematic reviews with meta-analyses could provide a comprehensive perspective for this critical part of pediatric ocular examinations.

CONCLUSIONS

Refractive errors in children are of great concern, as childhood is the period of binocular vision development. Accommodative power in children is at its maximum, which interferes with a reliable refraction assessment. Therefore, cycloplegic refraction is mandatory during childhood to obtain actual refraction, which is considered the cornerstone for eyeglass prescription. Knowledge of different cycloplegic agents used in childhood refraction is important for ophthalmologists and optometrists to obtain safe and effective cycloplegia. Manual retinoscopic refraction is the mainstay in pediatric refraction, and with the emergence of autorefractometers, the use of hand-held autorefractometers is now widespread for the detection of refractive errors in children. The presence of high refractive errors, anisometropia, or squint necessitate early prescription of eyeglasses to maintain binocularity and depth perception during childhood.

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