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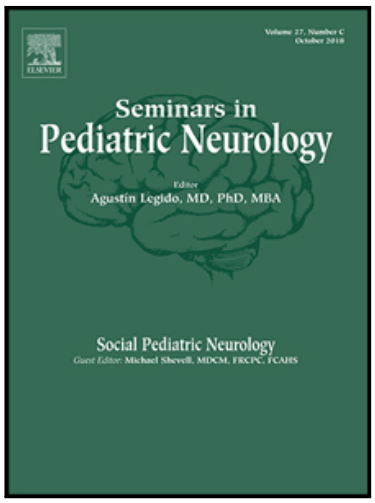

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Ocular Causes for Headache

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Abstract

Ocular causes of headaches include headaches associated with refractive error (HARE), convergence insufficiency (CI), and accommodative spasm (AS). HARE is more severe in patients with a high amount of refractive error. CI or AS patients can have diplopia and strabismus. Both CI and AS can be associated with head trauma or other systemic disorders. Headaches due to ocular causes are frontally localized occurring near the end of the day and are associated with increased amount of near work. HARE is treated with glasses while CI or AS may need other therapies such as prism, eye drops, surgery, or orthoptic exercises.

Keywords

Diplopia, Asthenopia, Eye Strain, Convergence Insufficiency, Refractive Error, Accommodative Insufficiency, Accommodative Spasm, Spasm of Near Reflex

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Introduction

Headaches can have a wide range of associated symptoms and can sometimes be related to the eyes. Pediatric patients are commonly referred to eye care providers for headache evaluation. These headaches can be associated with ocular or periocular pain, blurry vision, eye irritation, double vision, or pressure behind the eye.

A rise in the incidence of headache with eye strain symptoms has been observed in children as they are spending more time on digital devices [1]. Over the course of the COVID-19 pandemic, many countries have transitioned to distance learning to prevent the spread of the virus. This change in educational setting and structure has resulted in children using computers, laptops, smartphones, and tablets almost exclusively and for prolonged periods throughout the day. Mohan et al. conducted a survey during the COVID-19 pandemic as part of their Digital Eye Strain among Kids (DESK) study, showing that 96.3% of children were attending online classes and 36.9% of children in the study spent more than 5 hours on digital devices [1]. 50.23% of children in the DESK study reported digital eye strain (DES) symptoms such as headache and eye irritation. This is more than double the prevalence of DES symptoms (19.7%) in children reported in a recent meta-analysis study performed in 2015 [2].

An awareness and understanding of the potential ocular etiologies of headaches are becoming increasingly more relevant and necessary during the COVID-19 pandemic. The Third Edition of the International Classification of Headache Disorders (ICHD-3) published in 2018 lists four categories for "Headache attributed to a problem with the eyes" [3]. These categories are "Headache attributed to refractive error," "Headache attributed to acute angle-closure glaucoma," "Headache attributed to ocular inflammatory disorder," and "Trochlear headache." These ocular etiologies can be difficult to differentiate for healthcare providers who are not familiar with ocular diseases and disorders. In this

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review, we aim to focus on describing headache attributed to refractive error (HARE) [4] as well as headache associated with convergence insufficiency (CI) and accommodative spasm (AS) that may arise from increased near work as well as strategies for treatment and management of these headaches.

Headache Attributed to Refractive Error

According to the ICHD-3, headaches associated with refractive error are characterized as "mild headaches localized to the frontal region and the eyes themselves, worsened by prolonged visual tasks and associated with hypermetropia or astigmatism" [3]. Lajmi et al. described HARE as chronic, progressive, daily, and tending to occur near the end of the day while decreasing on weekends and vacations [4]. HARE was usually localized to the frontal and orbital areas although bitemporal and occipital headaches were also described. Pressure and compression sensations were common as well as associations with tingling and tearing from the eyes. Thorud et al. also described an association between HARE and upper body musculoskeletal symptoms such as tenderness in the upper shoulder and pericranial areas [5]. HARE was mostly moderate in intensity and triggered by prolonged exposure to screens and reading outside of work [4]. Most patients with HARE recovered spontaneously or alleviated their symptoms with sleeping, resting, or pain medications.

Patients with HARE in the Lajmi et al. study exhibited a relationship between their headaches and the amount and type of refractive error they had [4]. Patients with moderate amounts of anisometropia, or difference in refractive error between the two eyes, as well as astigmatism tended to experience visual blur. Patients with hyperopia or farsightedness experienced sustained accommodative effort while patients with myopia or nearsightedness experienced contraction of their scalp and periorbital muscles in order to squint and narrow the palpebral fissures and subsequently to create a pinhole effect. The pinhole effect is based on the concept that when light passes through a small opening the unfocused

rays are blocked, leaving only focused light to reach the retina which creates a sharper image [6]. HARE was suggested to be more severe in patients with hyperopia compared to myopia and more severe in patients with a higher amount of refractive error and astigmatism [4]. Gunes et al. reported that mild to moderate amounts of refractive error and especially astigmatism can also trigger migraine [7].

Prolonged exposure to screens is a major risk factor for developing HARE [4]. Heus et al. showed that 46-88% of computer users experience eye strain associated with headaches [8]. Thus, HARE can be relieved by evaluating patients for refractive error and subsequently correcting the refractive error by glasses or contacts. This highlights the importance of referring patients to an eye care provider when HARE is suspected. Limiting near work, taking regular breaks from screen use, and increasing variation in tasks can also alleviate symptoms related to HARE [4]. A guideline promoted by the American Academy of Ophthalmology that many ophthalmologists use with their patients is the “20-20-20 rule” which recommends taking a 20 second break every 20 minutes during near work to view a distant object at 20 feet, such as something outside a window or at the end of a room [9]. Blue lens filters which have been popularized in some practices to reduce eye strain during computer use are not recommended by the American Academy of Ophthalmology due to the dearth of scientific evidence for this purpose. Singh et al. showed that blue light blocking lenses did not have a significant effect on the signs or symptoms of eye strain associated with computer screen use [10].

On another note, patients with prism in their glasses used to treat diplopia related to extraocular muscle misalignment can also develop frontal headaches [11]. These symptoms can be more severe in patients who have vertical prisms in their glasses for vertical diplopia such as that caused by a trochlear nerve palsy. It is thus important to have these patients re-evaluated by their eye care providers to adjust the amount of prism in the glasses or to consider alternatives to treating diplopia such as surgery or

patching/ occlusion. The dominant or fixating eye is patched or occluded in children at risk for amblyopia which should also be determined by the eye care provider.

Headache Attributed to Convergence Insufficiency

Convergence insufficiency (CI) is a binocular vision disorder that was first described by German ophthalmologist, Dr. von Graefe, in 1855 [12]. CI consists of 3 components [13, 14]:

1. Exophoria or intermittent exotropia (i.e., a latent or manifest deviation of the eyes in which the eyes appear to drift outward) greater at near than at distance
2. A remote near point of convergence (NPC) (i.e., the distance at which the eyes are no longer able to converge, measured from the bridge of a patient's nose) greater than 10 centimeters
3. Decreased fusional convergence amplitudes at near (i.e., the amount of convergence induced by increasing amounts of base out prism held in front of a patient's eye that a patient can tolerate before experiencing diplopia while looking at a target at 33 centimeters) with normal fusional convergence amplitudes at near being 38 prism diopters

The prevalence of CI has varied greatly in previous reports, ranging from 1.75-33.0% [12]. Kratka and Kratka reported that 75% of patients with CI were symptomatic and most were diagnosed between the ages of 20 to 40 years old [15]. Only 2.25-8.5% of school-aged children evaluated in North American elementary schools in the 1970's and 1980's had a diagnosis of CI [12, 14, 16]. The authors suggested that adults spent more time doing near work than children did during this historical period. However, now that online learning and smartphone/ tablet use are widespread among children around the world and especially during the current pandemic, there has been a corresponding increase in the prevalence of CI in children. In their 2018 study, Menjivar et al. reported that 20% of children from the ages of 9 to 14 years old in central Ohio elementary and middle schools in the United States exhibited some component of CI [17].

The most common reported symptom for patients with CI was discomfort after reading or computer work at the end of the day [12]. Patients with CI can also present with diplopia, headache, blurry vision, and loss of place while reading or performing near work. Other symptoms included a frontal headache, eye ache, pulling sensation, heavy eyelids, sleepiness, diplopia, loss of concentration, blurry vision, tearing from the eyes, and a dull orbital pain. Less common symptoms included nausea, motion sickness, general fatigue, poor depth perception, and migraine. Lavrich revealed that CI can be a trigger for migraine and that migraine tends to occur immediately after performing excessing near work in patients with CI [18]. Migraine was shown to resolve with treatment of the CI although they were also brought on by the convergence induced by the treatment. A questionnaire developed by the Convergence Insufficiency Treatment Trial (CITT) study group [19, 20] called the Convergence Insufficiency Symptom Survey (CISS) consists of 15 questions designed to quantify the symptoms associated with reading and near work and can be found in the Appendix section of this article.

Accommodative insufficiency (AI) or decreased/ poor accommodation has been linked to CI [21]. Accommodation is the ability of the eye to change the refractive power of the human crystalline lens to focus images on the retina at different distances [22]. This ability is produced by a contraction of the ciliary muscle of the eye which is part of the iris or the colored part of the eye. This contraction allows the crystalline lens to increase its curvature and thus increase its refractive power. Accommodation is minimally present at birth and improves rapidly by the age of 6 months. This ability is the most robust during childhood but will then rapidly decline after the third decade of life. The most rapid decrease in accommodation occurs between age 20 and 50. This irreversible loss of accommodation associated with aging is called presbyopia and is why older adults have difficulty reading and doing near work without bifocals or reading glasses. Although one would not suspect accommodative insufficiency in a young

individual, there have been numerous reports of AI in children [23]. Because accommodation is stimulated by the convergence of the eyes that occurs when looking at something up close, a deficiency in accommodation can potentially be related to a deficiency in convergence. Marran et al. showed that 58% of children with CI also had AI [24]. Eye care providers can evaluate for concurrent AI in patients with CI by measuring accommodative amplitudes and a patient's near point of accommodation.

Most cases of CI are idiopathic but there are cases that have been associated with a variety of comorbid conditions including ocular, neurologic, and widespread systemic conditions. These conditions include a wide interpupillary distance, delayed development, toxemia, endocrine disorders, head trauma, stroke, encephalitis, drug intoxication, mononucleosis, hepatitis, and malnutrition [25]. A genetic component to CI has also been proposed due to the high prevalence of CI within families [26].

Patients who have head trauma from motor vehicle accidents and gunshot wounds have been found to have associated CI [27]. CI was more likely to occur in patients who were in a coma for a longer period of time or if they had cognitive disturbances after their head trauma. Cohen theorized that the permanent damage to mesencephalic and cortical brain structures after a traumatic brain injury is what ultimately leads to a decreased ability to converge the eyes. Ciuffreda revealed that the most common diagnosis in patients referred to an optometry clinic with an acquired brain injury secondary to either trauma or a cerebrovascular accident (CVA) was symptomatic CI [28]. Ohtsuka et al. specifically found an association between CI and left middle cerebral artery occlusion in their case report of a 31-year-old man [29]. CI can also be associated with Grave's disease, Duane's syndrome, and Parkinson's disease. Racette et al. showed that CI in Parkinson's disease can be improved with the use of levodopa [30].

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The management of CI is determined by eye care providers and can include observation, prescription of reading glasses or bifocals, base-in prisms, or orthoptic training [31]. Orthoptic training refers to visual exercises that are designed to increase a patient's fusional convergence amplitudes. These exercises include pencil push-ups, stereograms, and computer-based exercises that can be practiced at home or in the clinic. Most of these exercises involve having the patient look at a target such as a pencil or a tongue depressor with a picture or Snellen chart letters on it at a given distance and then gradually decreasing that distance until the patient experiences diplopia [32]. It should be noted that orthoptic training provided in the clinic has been shown to be much more effective than home-based therapies [32, 33].

Headache Attributed to Accommodative Spasm

Accommodative spasm (AS) or spasm of the near reflex (SON) is characterized as a triad of ciliary muscle spasm, esotropia (i.e., a manifest deviation of the extraocular muscles resulting in inward crossing of the eyes), and pupillary miosis that results from overstimulation of the parasympathetic nervous system and occurs involuntarily [34]. Symptoms of AS include intermittent episodes of diplopia and blurry vision, micropsia or macropsia (i.e., perceiving a minimized or magnified appearance of an image, respectively), fluctuating vision, headache, ocular pain, and dizziness. AS is a rare finding that is usually found in female pre-teens and adolescents.

The diagnosis of AS should be suspected if a patient is reporting transient episodes of diplopia and blurry vision rather than constant symptoms [34]. Patients with AS may have limited abduction when assessing motility with both eyes open. This motility deficit will disappear when each eye is tested individually with monocular occlusion. During an AS episode, the pupils may also become miotic. This finding will also resolve when either eye is occluded. It is important to have an eye care provider refract a patient with suspected AS before and after the administration of cycloplegic dilating eye drops. A key finding in

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a patient with AS is that the patient will appear to have a more myopic refractive error prior to dilation, which is referred to as pseudomyopia.

AS has been reported most frequently as a functional or psychogenic problem that can be associated with a conversion disorder and or the presence of psychosocial stressors [34]. Papageorgiou et al. showed a link between AS and prolonged daily screen time. Other etiologies include head trauma and very rarely, neurologic diseases such as myasthenia gravis, multiple sclerosis, meningitis, pituitary tumor, Arnold Chiari malformation, photosensitive epilepsy, and stroke, as well as drug toxicity from ocular or systemic medications. These medications are typically cholinergic agents such as topical pilocarpine eyedrops or oral physostigmine and donepezil but AS has also been reported with the use of topical bimatoprost [35] as well as oral antihistamines [36]. AS due to head trauma is thought to result from a lesion of the upper brainstem, left temporal lobe, frontal and parieto-occipital lobes, and the cerebellum, as shown by the interpretation of neuroimaging studies [37].

AS can be treated with cycloplegic agents such as cyclopentolate or atropine eye drops [34]. A glasses prescription with the full cycloplegic refraction can be given as well as bifocals. Other therapeutic options include partial occlusion, botulinum toxin injection of the medial rectus muscles, or surgery. A psychiatric referral may also be warranted in some patients.

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Trochlear Headache

Trochlear headache (TH) is defined by the ICHD as headache due to trochleitis and includes primary trochlear headache [3]. Trochleitis is due to inflammation of the trochlear complex while primary trochlear headache is non-inflammatory in etiology. The trochlea is a pulley-like structure located in the superonasal aspect of the orbit that contains the tendon of the superior oblique muscle. TH is

characterized by continuous pain localized to the trochlear area that is severe and associated with episodic exacerbations. Pain can be worsened by palpation of the trochlear area as well as elevation of the eye in abduction or depression of the eye in adduction, movements which stretch and contract the superior oblique muscle, respectively. Although most cases are idiopathic, some cases can be associated with systemic autoimmune diseases such as granulomatosis with polyangiitis and adult-onset Still's disease [39]. Treatment can be achieved with local injection of corticosteroids or high dose systemic non-steroidal anti-inflammatory drugs.

Headache Attributed to Intraocular Causes

The two remaining categories for ocular causes of headache listed by the ICHD-3 are "Headaches Attributed to Acute Angle Closure Glaucoma" and "Headaches Attributed to Ocular Inflammatory Disorder" [3]. Acute angle closure glaucoma (AACG) is considered an ocular emergency that is caused by an acute blockage of the ocular drainage system which results in a dramatic increase in intraocular pressure and subsequent damage to the optic nerve resulting in glaucoma. Ocular inflammatory disorders (OID) include uveitis, scleritis, conjunctivitis, and endophthalmitis. Although these disorders may present with headache, ocular symptoms like blurry vision, photophobia, eye irritation and redness, and eye pain are much more prominent. Because AACG and OID are due to intraocular causes that predominantly manifest as ocular symptoms and key clinical findings on slit lamp examination, they are more likely to be managed initially by an eye care provider. An attack of AACG classically presents as a severe headache with colored haloes around lights and nausea or vomiting as well as blurry vision that may persist even after the headache has subsided [40]. For the purposes of this review, we will not go into further detail describing AACG or OID.

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Discussion

Patients with headaches due to ocular etiologies who are referred to eye care providers by primary care providers or other specialties can have uncorrected or under corrected refractive error, convergence insufficiency, and/ or accommodative spasm. Patients with HARE have more severe headaches if they are farsighted rather than nearsighted, if they have a high amount of farsightedness or nearsightedness, or if they have a high amount of astigmatism. Patients with headaches due to CI or AS can have associated diplopia and extraocular muscle misalignment whereas patients with HARE will not usually possess these findings. An outward deviation of the eyes can be detected in patients with headaches due to CI while an inward deviation of the eyes can be detected in patients with headaches due to AS. The most common cause of CI is usually idiopathic while AS is usually psychogenic. Both CI and AS can be associated with head trauma or other neurologic or systemic disorders, although this is less common. Patients with HARE and headaches due to CI and AS usually characterize their headaches as frontally located, occurring near the end of the day, and are associated with eye strain and an increase in the amount and duration of near work or prolonged screen time. Patients with HARE can be treated with a prescription for glasses or contacts whereas patients with headache due to CI can get bifocals and/or prisms prescribed as well as orthoptic training. Patients with headache due to AS can be treated with glasses, cycloplegic eye drops, Botox, or surgery.

Other ocular etiologies resulting in headache include trochlear headache, headache attributed to acute angle closure glaucoma, and headache attributed to ocular inflammatory disorders.

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Conclusion

An increase in referrals to healthcare providers for headache and eye strain has been documented as children are spending more time doing near work on digital screens [1]. Now, especially in the setting of the COVID-19 pandemic, it is crucial to recognize and understand the underlying ocular etiologies of these headaches in order to better manage patients' symptoms by working together with eye care providers who can then prescribe glasses or other therapies.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Convergence Insufficiency Symptom Survey (CISS)

Clinician/Assistant Instructions: Pose the following questions exactly as written. If the patient responds with "yes" – please qualify with frequency choices. Do not give examples.

Patient instructions: Please answer the following questions about how your eyes feel when reading or doing close work.

	Never (0)	Infrequently/ not very often (1)	Sometimes (2)	Fairly often (3)	Always (4)
1. Do your eyes feel tired when reading or doing close work?					
2. Do your eyes feel uncomfortable when reading or doing close work?					
3. Do you have headaches when reading or doing close work?					
4. Do you feel sleepy when reading or doing close					

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work?					
5. Do lose concentration when reading or doing close work?					
6. Do you have trouble remembering what you have read?					
7. Do you have double vision when reading or doing close work?					
8. Do you see words move, jump, swim, or appear to float on the page when reading or doing close work?					
9. Do you feel like you read slowly?					
10. Do your eyes ever hurt when reading or doing close work?					
11. Do your eyes ever feel sore when reading or doing close work?					

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12. Do you feel a "pulling" feeling around your eyes when reading or doing close work?					
13. Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14. Do you lose your place while reading or doing close work?					
Total score: ____	_ x 0	_ x 1	_ x 2	_ x 3	_ x 4

For Children (<age 21): total score = 16 or higher is suggestive of convergence insufficiency.

For Adults: total score = 21 or higher is suggestive of convergence insufficiency.

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