CONVERGENCE INSUFFICIENCY

One of the most common disorders of binocular vision encountered in the eye clinic is convergence insufficiency (CI). Population studies estimate upwards of 8% of the population suffer from convergence insufficiency, with the incidence increasing with age. Convergence insufficiency results with vergence ability at near is unable to match vergence demand. When this occurs, sensory fusion may be disrupted leading to intermittent diplopia, asthenopia, and fatigue. Clinicians should be able to quickly screen for abnormalities in convergence ability of a patient and provide a thorough evaluation of binocular ability when indicated. Many patients will respond well to vergence therapy, leading to both an increase in fusional vergence ability and a subsequent decrease in symptoms.

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KEYWORDS

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Convergence

Vergence eye movements are disconjugate actions that provide gaze control which, together with pursuit and saccadic eye movements, allow people to visually locate themselves and other objects in the environment.[1] Convergence changes the angle between the two eyes' visual axes by engaging each medial rectus muscle, the curvature of the crystalline lens is increased due to constriction of the ciliary muscle, and the pupil constricts; divergence engages the lateral recti, the lens flattens as the ciliary muscle relaxes, and the pupil widens. This series of actions helps to locate, fixate, focus on, and extract spatial data from objects in the three-dimensional world. The exact control of vergence eye movements is not clear; however, input from the visual cortex, midbrain, thalamus, and cerebellum have been suggested.[1]

To move the eyes effectively and foveate a near stimulus, convergence needs to be very accurate and to cover the full extent of visual space. Convergence also needs to be stable over time. Both requirements of the convergence systems may be stressed on a daily basis as the demands placed on the visual system in today's culture often require long periods of accurate, sustained convergence for reading, whether from paper or display screens. Convergence insufficiency is a condition in which the visual system is unable to obtain or maintain convergence adequate for comfortable binocular vision, especially at near distance. As a result, the two eyes' visual axes do not intersect on the object being viewed. CI is classically defined as exophoria at near with reduced near point of convergence (NPC) and reduced positive fusional vergence (PFV).[2]

Convergence insufficiency is a relatively common binocular vision disorder that eye care professionals should identify.[3] The reported prevalence of CI ranges from about 2% to 8% for both pediatric and adult populations, with an increase in prevalence with advancing age.[4]

CI symptoms vary widely and many patients are unaware that their reading difficulties can have a visual basis. Symptoms include fatigue or discomfort with reading, computer, or other near work; headache or eye ache; difficulty concentrating; and double vision, among others. Patients suffering from CI may also experience motion sickness symptoms such as nausea and dizziness.[5] Symptoms are predominantly worse during the viewing of near objects, impacting tasks such as reading, schoolwork, computer use, cell phone use, and the like. The discomfort associated with CI often leads to avoidance of tasks that place significant demands on the convergence system.

Testing for CI

CI patients generally see clearly (perhaps with an optical prescription), so they often do not recognize vision as the basis for their difficulties, making it important for eye care practitioners to screen for CI. The American Optometric Association suggests using a simplified screening for CI. The first step evaluates convergence ability using the penlight red/green (PLRG) procedure followed by the Convergence Insufficiency Symptom Survey (CISS) if the patient fails the PLRG test. For the PLRG test, the patient wears red/green glasses and fixates on a penlight as it is moved towards the patient's nose. The patient is asked to report when the light splits into a red and green light, which indicates when binocular fusion has been lost, and thus when the two eyes' visual axes are no longer both aligned with the light. Patients who report seeing the light break into red and green on the third of three repeated trials, at greater than 10 cm (~4 inches), are asked to complete the CISS.[6] By comparison, the average break point using the PLRG method of NPC evaluation is approximately 6 cm (~2.4 inches) in normal subjects.[7]

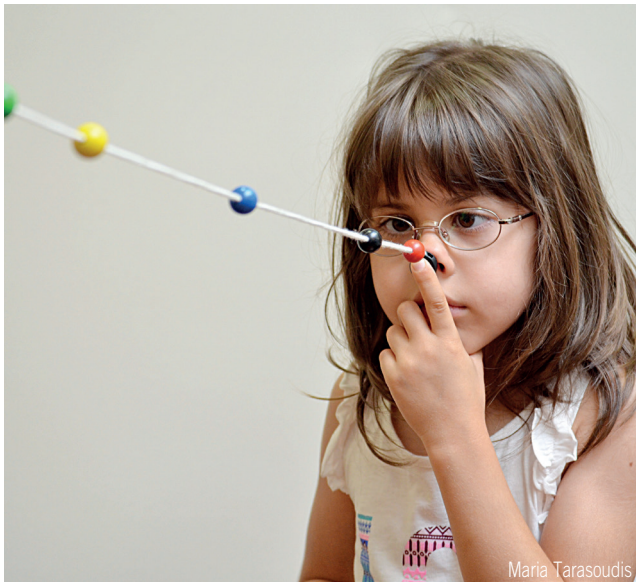
Formal testing of CI should include a cover test to evaluate eye posture

Improvement in vergence ability through a structured therapy program often significantly decreases symptoms of CI and subsequently increases a patient's quality of life.

Formal testing for CI requires a more thorough evaluation of the patient's binocular ability. Critical tests that should be performed include the cover test (unilateral and alternate) at both distance and near, vergence evaluation with prisms (prism bar or Risley prisms), near point of convergence, accommodation amplitude (push-up test), and accommodative facility. Evaluation of accommodation is important as some patients may show CI-like symptoms simply due to poor accommodation.[8]

Treatment

Vision therapy for CI is based upon the protocol set by the Convergence Insufficiency Treatment Trial (CITT), and consists of office-based vergence/accommodative therapy with home reinforcement.[3] A more recent trial completed by the Pediatric Eye Disease Investigator Group (PEDIG) evaluated the effectiveness of a home-based therapy and suggested that the home-based therapy alone had a less successful outcome compared to treatment that included in-office visits; however, recruitment was an issue for this study, and only one home-based therapy was tested.[9]



A patient using a Brock string to practice near fusion

Patients with CI often have weak positive fusional vergence, thus the early stage of therapy focuses on building convergence ability with slow, smooth vergence tasks. Convergence demand can be altered by moving objects closer and using smooth vergence, increasing the speed of a smooth vergence activity, and, ultimately, altering convergence demand rapidly with jump vergence-type activities to work on convergence facility.

The next stage of therapy for CI works the vergence ability of the patient in the opposite direction. Divergence activities build negative fusional vergence reserves and, similar to early therapy activities, divergence activities should begin with slow, smooth changes early and move to rapids demand changes using jump vergence-type activities later.

In the final stage of treatment, the patient's vergence facility should be challenged by altering convergence and divergence demand with changes in accommodation and eye positioning. Accommodative demand can be altered by including lenses and flippers into therapy, or by altering the location of targets in space (far-to-near). Pursuit and saccadic activities that also include changes to vergence and accommodative demand are included in this final stage. Improvement in vergence ability through a structured therapy program often significantly decreases symptoms of CI and subsequently increases a patient's quality of life.

It is interesting to note that visual rehabilitation of convergence appears to also produce measurable neurophysiological changes. Functional magnetic resonance imaging (fMRI) showed significant changes within the prefrontal cortex, frontal lobes, parietal lobes, cerebellum, and brain stem in patients who completed 18 hours of therapy.[10]
For many years, standard therapy for CI consisted of "pencil pushups." Prescribing this exercise was generally unsuccessful at solving the problem, in part because it was difficult to monitor compliance. The failure of pencil pushup therapy may be due to poor patient motivation during the exercise, a factor that is

essential for successful vergence rehabilitation.[11] More common therapeutic tools and activities are noted in table 1. These tools and activities primarily stress the patient's vergence or accommodative systems. A combination of vergence and accommodative therapy is critical for the final stages of a vergence rehabilitation therapy plan. Emerging technology may help by providing activities which create novel, therapeutic challenges for the oculomotor system, and allow for monitoring of patient progress. Patients may be more willing to engage with these new technologies, such as videogame or virtual reality systems, which may ultimately improve patient outcomes.

CI and Other Conditions

Head Injury

Visual sequelae following a head injury have become a critical concern for eye care professionals. Indeed, a history of traumatic brain injury significantly raises the prevalence of CI. A recent meta-analysis reported a prevalence of nearly 36% for CI in patients with post-traumatic brain injury. This included patients in both the military and general populations.[12] Convergence insufficiency is also closely associated with sports-related head injuries in children. Approximately 42% of athletes under the age of 18 displayed symptoms of CI following a sports-related concussion.[13]

COMMON TREATMENT TOOLS AND TECHNIQUES USED IN CI REHABILITATION

Tool/Technique	Primarily Trains
Brock string	Vergence
Vectograms	Vergence
Aperture rule (single, double)	Vergence
Lifesaver cards	Vergence
Computer- or VR-based vergence programs	Vergence
Prisms (BI/BO)	Vergence
Loose lens rock (monocular)	Accommodation
± Lens flippers (monocular, binocular)	Accommodation
Hart charts	Accommodation

Attention Deficit Hyperactivity Disorder (ADHD)

Vision plays a crucial role in attention. A 2015 meta-analysis reported the worldwide prevalence of ADHD in children age 18 and under to be 7.2%.[14] Unfortunately, patients suspected of having ADHD may not receive a visual examination as part of the evaluation process, and symptoms of ADHD and CI may overlap. The Diagnostic and Statistical Manual of Mental Disorders (DSM), 5th edition, notes a series of characteristics of inattention that may have a visual component. These include:

- careless mistakes in schoolwork, at work, or during other activities
- difficulty sustaining attention in tasks (e.g., lengthy reading).
- does not follow through on instructions and fails to finish schoolwork
- difficulty organizing tasks and activities
- avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework)[15]

A 2005 study at the University of California, San Diego reviewed over 1,700 patients diagnosed with ADHD. Of this cohort, 176 received an eye examination, and 15.9% of these patients were diagnosed with CI. This represents a nearly 3-fold increase of CI diagnosis compared to the national average.[16] Of importance to eye care providers is that visual symptoms of CI can cause confusion in the diagnosis of ADHD, and that ADHD symptoms can potentially be relieved with proper treatment of the CI.

Neurological and Systemic Disorders

Several serious disorders, including degenerative neurological disorders, masquerade as CI or cause

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complete paralysis of convergence. Parkinson's disease,progressive supranuclear palsy, cerebrovascular events in the thalamus or superior colliculus, thyroid eye disease, and myasthenia gravis all have the potential to adversely affect the vergence system.[8] Although less common, a thorough health history should help identify these more concerning causes of limited convergence.

Future of CI Treatment

Stereoscopes, synoptophores and other binocular instruments provide the appropriate stimuli for vergence therapy; however, they are labor intensive to use, and provide limited opportunities for interaction. Specially developed software applications, running on personal computers and tablets, have improved vergence rehabilitation therapy by integrating eye-hand coordination, vestibular input, and proprioception stimulation into classic `3vision therapy for CI. These technologies can provide dynamic and engaging activities that may result in better compliance with home therapy prescriptions. Virtual reality systems can take these benefits a step further by providing an immersive experience of the visual stimuli. Further advances in the use of virtual reality to treat CI can be expected in the near future, providing optometrists more tools for the management of CI.

KEY TAKEAWAYS

- Convergence insufficiency is a common binocular vision disorder with a prevalence of 2% to 8% of the population.
- Simple screening tests, such as the PLRG and CITT survey, is a quick way to identify possible CI.
- Suspected CI requires a more thorough binocular vision evaluation.
- Convergence insufficiency may also present in patient with a history of TBI, ADHD, and some neurological disorders.
- Convergence insufficiency responds well to vergence therapy.

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