Inconsistent diagnostic criteria for convergence insufficiency

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BACKGROUND Convergence insufficiency (CI) is a common entity but seems to be an ill-defined diagnosis that incorporates many near-vision symptoms. The current literature often varies in its criteria for diagnosis. Without a clear definition and standardization of the clinical examination, there is the potential for misdiagnosis and/or the inclusion of other diagnoses as CI. The purpose of this study was to assess the uniformity of diagnostic criteria in a well-defined practice environment.

METHODS The medical records of individuals diagnosed with CI between June 2007 and November 2014 who were patients of 6 fellowship-trained strabismologists in private practices and at Wills Eye Hospital clinics were reviewed retrospectively. Exclusion criteria included any previous treatments for CI, prior strabismus surgery, or other causes for strabismus, including cranial nerve palsies. The following data were collected: age, sex, race, age at diagnosis, past medical and family history, relevant symptoms, visual acuity, near point of convergence (NPC), strabismus measurements, and fusional amplitudes at distance with base-out and base-in prisms.

RESULTS A total of 387 patients fit our inclusion criteria and were analyzed in our study. There was no uniformity across clinicians in the clinical evaluation and diagnosis of patients with CI. The amplitude of the NPC was highly variable, and most clinicians did not assess the quality of the convergence movement or perform convergence fusional amplitude testing in making the diagnosis of CI.

CONCLUSIONS Our review has demonstrated the range of criteria within one group of practitioners to diagnose CI. This may reflect our current understanding and the need for an evidence-based definition of the disease and its diagnosis. (J AAPOS 2019;23:32.e1–4)

Reading and computer-use are essential to our lifestyle; thus, it is important to understand and recognize any clinical entity that can affect our patients' ability to see comfortably at near. Convergence insufficiency (CI) is the inability to maintain fusion on a near target.[1] It is found in up to 8.3% of all school-aged children and 15.7% of adults.[2] Common symptoms of CI include headaches, asthenopia, diplopia, and difficulty reading or performing tasks at near. Examination findings may include a decreased near point of convergence (NPC), decreased fusional amplitudes, and phorias and/or tropias.[3-6] Patients may not have all three findings.[7] Additionally, poor fusional amplitudes frequently found with CI can be familial.[8]

The major pediatric ophthalmology and strabismus textbooks do not define CI uniformly. The classic strabismus text by von Noorden states that "the diagnosis of CI is based on the finding of a remote NPC and decreased fusional convergence at near fixation. An NPC farther away than 10 cm is defective or remote. In patients with convergence insufficiency, it may be as remote as 25 or 30 cm or more."[1] Harley's textbook states that "CI is characterized by an exodeviation that is present only at near or greater than distance fixation."[9] There is no mention of NPC. The American Academy of Ophthalmology Basic and Clinical Science Course defines CI as an exodeviation greater at near fixation, poor fusional convergence amplitudes, and a "remote" NPC, for which no value is provided.[10]

The definition of CI based on examination findings varies throughout the literature. The normal NPC in unaffected children can be as close as 1–2 cm from the nasal bridge. Studies on CI have classified the NPC to be abnormal if it is >10 cm.[11] In the national multicenter

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studies of adults and children with CI, the Convergence Insufficiency Treatment Trial (CITT) and the Pediatric Eye Disease Investigator Group (PEDIG) included individuals with NPC of ≥6 cm.[12,13] Although normative data of NPC has been published for adults, no standardized value has been identified, because the NPC break varies by study from 5 cm to 10 cm and may recede with age.[14-16] Some researchers have described CI by Sheard's criterion: the amount of vergence a patient has with base-out prism testing (positive fusional vergence). If the positive fusional vergence is less than twice the phoria measurement, the patient is said to have CI.[4,17] However, the type of phoria at near can be variable, and both exo- and esophorias have been reported. More recently, CITT and PEDIG have described CI with mention of reduced fusional amplitudes at near.[12,13] We have found no studies addressing the quality of the convergence movement.

This study sought to further examine the criteria used in practice to diagnosis CI. The study reviewed the use of prevalent symptoms and clinical findings, such as NPC, strabismus measurements, and fusional amplitudes in the diagnosis of CI in pediatric ophthalmology practices.

Subjects and Methods

This study was approved by the Wills Eye Hospital Institutional Review Board. The medical records of all children and adults diagnosed with CI from the private practices and Wills Eye Hospital clinics of 6 fellowship-trained strabismologists were reviewed retrospectively. Patients included in the study were newly diagnosed with the ICD-9 code 378.83, "convergence insufficiency," between June 2007 and November 2014. Patients were excluded from the analysis if they had a prior history of strabismus surgery, treatment for CI, or any other cause for strabismus, including intracranial tumors or cranial nerve damage. All data was deidentified. The following data were collected: sex, race, age at diagnosis, past medical and family history, relevant symptoms, visual acuity, NPC, strabismus measurements, and fusional amplitudes at distance with base-out and base-in prisms.

NPC was assessed using a near target (accommodative or non-accommodative) with the object being moved toward the nose until one eye was observed to drift outward or the patient noted diplopia. The location in centimeters from the patient's nasal bridge at which the nondominant eye deviated or the patient noted diplopia was documented.

To exclude the motion of convergence, fusional amplitudes were measured at distance only. We measured convergence amplitudes before divergence amplitudes, because patients have been noted to fatigue with smaller convergence amplitudes following divergence amplitude measurements. Convergence fusional amplitude (CFA) testing entailed using a standard base-out horizontal prism bar from 1^{Δ} to 40^{Δ} placed over one eye starting at 1^{Δ}. This was slowly increased while the patient was asked to maintain fixation on a target at distance (minimum 3 m) until the patient could no longer fuse the images, and the break point was recorded. The prism was then slowly decreased until the patient could fuse the images again; this was recorded as the recovery point. We did not measure the point at which blur occurred.

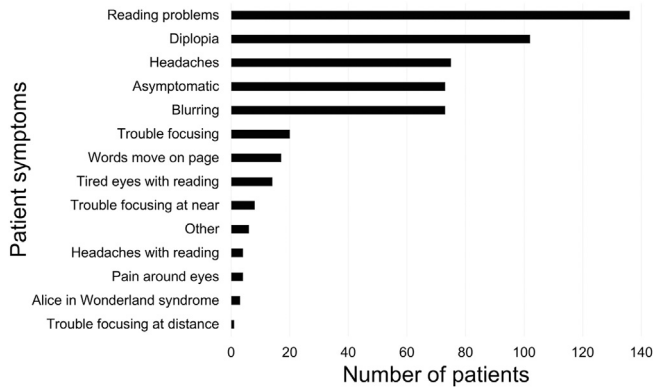

FIG 1. Clinical symptoms of convergence insufficiency reported by patients.

Divergence fusional amplitude testing was performed after CFA measurements and consisted of using a standard base-in horizontal prism bar from 1^{Δ} to 40^{Δ} placed over one eye starting at a 1^{Δ}. This was slowly increased while the patient was asked to maintain fixation on a target at distance (minimum 3 m) until the patient was no longer able to fuse the images. The break point was recorded. The prism was then slowly decreased until the patient could fuse the images again; this was recorded as the recovery point. We did not measure the point at which blur occurred. Descriptive statistics were used to analyze the data with the use of R Project for Statistical Computing.

Results

Of the 827 patients initially reviewed, 440 did not meet inclusion criteria. Of the remaining 387 patients, 54% were female. Patients ranged in age from 3 to 90 years. There were 279 patients (72.1%) <18 years of age, with a mean age of 9 ± 2.97 years (standard deviation); the mean age of patients >18 years was 48.96 ± 17.49 years. Nineteen percent of the patients were asymptomatic. Symptoms by frequency are presented in Figure 1. The most common symptoms elicited included difficulties with reading (35% of patients), diplopia (26%), headaches (19%), and blurring (19%). Other symptoms described included trouble focusing, words moving on a page, tired eyes while reading, trouble focusing at near, pain around the eyes, headaches with reading, and trouble focusing at distance.

Ninety-four percent of patients had best-corrected visual acuity better than 20/30 in both eyes. The majority (72%) of our patients had either no refractive error or were hyperopic. The average NPC of all patients was 3 ± 2.97 cm, with 7 patients (2%) having an NPC recorded as 0 cm or "to the nose," 20% having an NPC of 1 cm, 37% of <2 cm, and 49% of <3 cm. Therefore, half of our patients were diagnosed with CI with normal NPCs.

Only 246 of patients (29.7%) diagnosed with CI had documented fusional amplitudes. For analysis of fusional amplitudes, the patients were divided into three groups, depending on the NPC, due to the varied NPC measurements documented in the literature. The current literature defines CI with an NPC >5–6 cm, depending on the study. Therefore, patients with an NPC of <4 cm would then be considered normal To further delineate why patients with "normal" NPC were diagnosed with CI by our clinicians, we created groups to explore the trends in these patients. Therefore, in our study, we defined three groups, as follows: group 1, with an NPC of 1, 2, or 3 cm; group 2, with an NPC of at least 4 cm; and group 3, with all ranges of NPC. The average CFA break point for group 1 was $18^{\Delta} \pm 8.9^{\Delta}$; for group 2, $16^{\Delta} \pm 5.9^{\Delta}$; and for group 3 was also $18^{\Delta} \pm 8.9^{\Delta}$ which was statistically significant ($P < 0.001$). Overall, the CFAs were significantly higher in groups 1 and 3 compared to group 2. The difference between the CFA break point and recovery point was $10^{\Delta} \pm 5.9^{\Delta}$ in group 1 and was $6^{\Delta} \pm 5.9^{\Delta}$ in group 2, also statistically significant ($P < 0.001$).

Distance strabismus measurements did show some statistically significant findings between NPC groups. In group 3, 8.5% of patients had esophoria at distance, 32.8% were orthophoric, and 54.8% had exophoria. In group 1, 8.8% had esophoria, whereas in group 2, 8.3% had esophoria ($P = 0.857$). The distance measurement was orthophoria in 28.8% of patients in group 1 compared with 40.8% of patients in group 2 ($P < 0.001$). Exophoria was present in 65.7% of patients in group 1 and 45.1% in group 2 ($P < 0.001$). The percentage of patients with near strabismus measurements of esophoria, orthophoria, and exophoria were not statistically different between groups. At near, exophorias were found most commonly in 32.8% of patients and esophorias were found in 7.5%.

Asymptomatic patients were also found to have CI. These patients had a greater exophoria at near than at distance or had an NPC of ≥4 cm. The group of asymptomatic patients was excluded from the symptomatic patient grouping and was examined in a separate analysis to determine whether any characteristics on examination differentiated them from the symptomatic patients. These asymptomatic patients exhibited a lower NPC compared to patients who were symptomatic ($P = 0.004$). Their fusional amplitudes exhibited no difference from symptomatic patients.

Discussion

Characteristics of CI as seen by 6 fellowship-trained strabismologists are reflected in our paper. Previously reported common symptoms described in CI include headaches, asthenopia, diplopia, and difficulty reading or doing tasks at near.[3,6] Our data agreed with prior reports of these symptoms, with 81% of the patients reporting some combination of these symptoms.

Patients diagnosed with CI had one or multiple of the following: symptoms, a reduced NPC, and/or reduced CFA. This study was not designed to identify the prognostic value of these measures but rather to report the usage and results of these tests. There was no uniformity across clinicians in the clinical evaluation of patients with CI.

Fusional amplitudes were recorded least frequently. The human fusional response is twofold; it considers the motor component along with the sensory component.[18] Motor changes include vergence eye movements and the sensory component relates to Panum's fusional area.[18] A fusional amplitude is the sum of the sensory and motor components of a fusional response.[18] Mazow[6] and von Noorden[1] in the early 1970s and, more recently, Fray[19,20] described the proper technique for measuring fusional amplitudes, including the importance of documenting the alertness of the patient who is being tested, measuring divergence break/recovery first before convergence break/recovery in normal binocular patients, and standardizing a method for using distance and near fixation targets, although this has not become a standard of practice, as seen in our study. Of note, in her 2017 study, Fray[20] mentions that the order of testing of fusional amplitudes should be based on symptoms and recommends measuring CFA before divergence fusional amplitudes in symptomatic patients with exodeviations, as seen in CI.[20] One of our clinicians used distance fusional amplitudes as a supportive finding in the diagnosis of convergence insufficiency. We know of no study describing the sensitivity or specificity of using distance versus near fusional amplitude testing in making this diagnosis.

Overall, there is very little mention in the literature about fusional amplitudes, and reported normal values vary greatly. Normal distance CFAs, measured with base-out prisms, have been described as ranging from 18^{Δ} to 26.8^{Δ}[6,19,20] and in some instances up to 32^{Δ}.[21] Normal near CFAs have been described ranging from 30^{Δ} to 36.6^{Δ}.[6,19,20] There has been limited research describing the normal differences between convergence fusional break and recovery.[6,19,20] This research study describes the average CFA in CI patients with respect to the NPC and suggests that patients with CI and smaller NPCs have larger CFAs than those patients with CI and larger NPCs, and this is statistically significant. Thus, a more severe CI has smaller CFA than a less severe one.

Additionally, the present study describes patients with CI that have NPCs at 1 cm but are symptomatic. Previous studies have described NPCs of 5–6 cm or greater in the context of CI. One investigator in our study observed that some of these patients had notable difficulty with the convergence movement, described as slow, strained, or jerky. We found no studies describing the quality of the convergence movement or addressing an abnormal convergence movement except in terms of NPC. Other patients with NPC at 1 cm had no visible difficulties with the convergence reflex, although they exhibited significant symptomatology of CI and had poor fusional amplitudes. It is possible that these patients with a normal convergence,

although similar in symptomatology, may not have true CI and that poor fusional amplitudes alone may a subset within this disease or a separate diagnosis.

When evaluating strabismus in relationship to the NPC, patients with a low NPC (1, 2, or 3 cm) had a statistically significant higher likelihood of being orthophoric at distance compared to patients with an NPC of ≥4 cm. Those with low NPC (1, 2, or 3 cm) also had a higher likelihood of being exophoric at distance than those with a higher NPC. This relationship was not true for esophoria. It is unclear how esophoria can occur with convergence insufficiency, but it may be related to overaction of the accommodative reflex.

In this study, asymptomatic patients had a smaller NPC than symptomatic patients. The fusional amplitudes of symptomatic and asymptomatic patients do not differ statistically.

CI requires further study and definition. The data indicates that CI has been diagnosed with an NPC as low as 1 cm. CFA may provide further clarity in the diagnosis of CI. Consistent diagnosis of CI requires standardization of clinical examination to prevent confusion and misdiagnosis.

Literature Search

PubMed and Google Scholar were searched in June 2018 for English-language results using the following terms and combinations: *convergence insufficiency*, *exophoria*, *fusional amplitudes*, *near point of convergence*, *vision therapy*, *vergence training*, *convergence insufficiency* AND *diplopia*, *convergence insufficiency* AND *asthenopia*.

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