Convergence insufficiency: incidence, diagnosis, and treatment

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ABSTRACT — Convergence insufficiency is one of the most common ocular problems. The paper carefully reviews the existing literature paying particular attention to etiology, diagnosis, sensory findings, treatment, and treatment results.

KEY WORDS—Convergence insufficiency, accommodation, near point, phoria, fusional convergence, vision training

Convergence insufficiency (CI), as it has been described in the literature, is a syndrome consisting of a receded near point of convergence, exophoria at near, reduced positive relative convergence, and reduced negative relative accommodation.1 However, since few patients manifest all four characteristics in their presentation of symptomatology, few clinicians define CI in this manner. In fact none of the authors cited in this paper employ this definition. Generally CI is defined as a reduction in the positive relative convergence in relationship to the demand and/or the reduction in the near point of convergence, i.e., a deficiency in fusional, tonic, accommodative and/or voluntary convergence. Since this condition is relatively common and may cause abnor-

mal visual behavior and undesirable symptomatology, a literature review is both warranted and important in order to dispel inappropriate clinical impressions and to reaffirm a basic understanding of this binocular anomaly.

Incidence
Clinical studies show a large difference in incidence of convergence insufficiency. These differences may be attributed to the definitions of CI being used, the populations being studied and methods of measurement.

CI has been said to occur in 1% of normal children and 15% of adults.2 Kratka has found that 25% of a sample of 500 patients demonstrated findings indicative of CI.3 Seventy-five percent of these patients exhibited symptoms. Other findings include: 2.8% by White and Brown;4 2.5% by Maun; between 3.1% and 4.9% by Kent and Steeve;5 11% of patients aged 40 and under by Mahto;6 and 1.75% by Norn.7

Many authors feel that convergence insufficiencies are not of significant importance in children since symptoms do not appear until the second or third decade of life.8910 During this period young adults are involved with the greatest amount of near point work, and will seek help to alleviate symptoms. Children, on the other hand, do not utilize their eyes as much on near point activities and, therefore, may not experience any discomfort. In addition, children are less specific about symptoms, cannot relate them to function, and may avoid symptom-producing tasks. It is interesting to note that Allen et al11 found that approximately 5% of a school population, between kindergarten and 6th grade, had a reduced near point of convergence and 6% of the children failed a near cover test. These percentages are similar to the percentages of young adults presenting symptoms. Perhaps the children who demonstrate objective signs of a convergence insufficiency earlier in life, do not experience symptoms until later on, when the visual demands placed upon them are sufficiently stressful to produce discomfort.

Presbyopes also demonstrate convergence insufficiency. However, the etiology here may be different than in a younger population where the individuals still have the use of accommodative convergence. Presbyopes who

“The near phoria measurement is the amount of accommodative and tonic convergence in use at a given distance.”

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develope CI usually do so as a result of a loss in accommodative convergence and may be successfully treated with vision training.\(^2\) Induced BO prism effect as a result of bifocal lenses, may be another cause of CI in presbyopes. This is especially true in aphakics wearing high plus prescriptions.

More females than males present CI in a ratio of 3:2.\(^{1,11}\) Manson\(^4\) postulated that this difference may be due to anemia secondary to gynecological, obstetric and/or menstrual problems.

**Symptoms**

The most frequent symptom found in CI is discomfort after reading or near work.\(^{1,11}\) and this usually occurs at the end of the day.\(^{11}\) Other symptoms include: frontal headaches;\(^4\) eye aches, pulling sensations, heavy eyelids;\(^4,11\) sleepiness, diplopia;\(^6,8,13,16\) loss of concentration;\(^1,4,8,13,16\) teardrop;\(^1,4\) and dull orbital pain. Less common complaints include nausea, motion sickness, dizziness;\(^2,4,11\) panoramic headaches;\(^4,11\) gritty sensations in the eyes and general fatigue. In addition, it has been noted that some CI patients report poor depth perception, e.g. trouble parking a car; trouble playing tennis.

Hirsch\(^7\) reported the incidence of various symptoms in a CI population. He found that 38% of CI patients had ocular fatigue, i.e. discomfort or drowsiness; 25% experienced headaches; and 18% had aching, stinging, burning and/or tearing of the eyes. In another study, Kent and Steeves\(^4\) found that 60% of their population of CIs had headaches, 49% experienced blurring of print, 34% had ocular fatigue, and 21% had intermittent diplopia. Eighteen percent of patients with CI are asymptomatic.\(^7\) This absence of symptomatology may be due to either suppression,\(^13\) avoidance of near visual tasks,\(^13\) high pain threshold or monocular occlusion.

Various authors have observed a high percentage of neuroses and anxiety reactions associated with symptomatic CI. Mann\(^7\) and Nawratzki and Avrouskine\(^3\) have implicated the psychological problem as the cause of the CI since these patients manifest symptoms more frequently than the normal population. However, these authors have not provided any direct evidence that neuroses and anxiety reactions cause CI. Furthermore, it is reasonable to suspect that sustained near point discomfort might produce nervousness, tenseness and anxiety. It is the authors' experience to see mild degrees of tension and nervousness disappear after successful treatment of CI. If CI were a result of psychological imbalance, then one would not expect to find a high success rate with visual therapy alone. (See treatment results.) Therefore, the authors feel that the psychological component may be a manifestation of CI rather than a cause.

**Findings**

A. Phoria

The near phoria measurement is the amount of accommodative and tonic convergence in use at a given distance. The near phoria also represents the amount of fusional convergence demanded for single binocular vision.\(^2\) Passmore and MacLean\(^4\) found that 79% of their CI population demonstrated exophoria at near, 18% orthophoria, and 3% esophoria. In another study, Cushman and Burri\(^11\) found 63% of CIs exhibited an exophoria on a near cover test. Though most patients with CI demonstrate an exophoria, it is neither needed nor necessarily the cause of symptoms.

B. Fusional Convergence

Fusional convergence or positive fusional reserve is the amount of convergence available to overcome temporal disparity in order to obtain fusion. Various authors\(^5,13,22\) have reported low positive fusional reserves in CI. Mould\(^3\) and Passmore & MacLean\(^4\) consider 8-10 p.d. low. Mayou\(^11\) reports 10-20 p.d. to be low; Hirsch\(^7\) defines low as 12 p.d.; and Norn\(^7\) uses 15 p.d. Reduced positive fusional reserves correlate highly with symptomatology. It should be noted that convergence findings vary with stimula Specialists. Illumination, speed of measurement and instrumen
tional set. These factors may account for the differences reported by various authors.

Another criterion for the assessment of fusional ability is the recovery point. This is defined as the point at which fusion, after being broken, is re-established. Fusional recovery consists of voluntary convergence, and convergence in response to temporal disparity. Hirsch\(^7\) reported that recoveries will be low in CIs. Davies\(^7\) stated that if the addition value is high and the recovery is low, treatment will be of shorter duration than if the addition value itself is low.

The authors feel that the recovery point is probably a better indication of fusional potential over time since it represents the patient's ability to voluntarily regain fusion on the basis of sensory information.

C. Near Point of Convergence (NPC)

A receded near point of convergence has been described by Duane\(^1\) as the most consistent finding in CI. These findings have been reported to be beyond 13.1 cm, 9.5 cm, and 3 inches. Davies\(^1\) recommended that the NPC be performed 12 times to evaluate ocular fatigue.\(^2\) According to Davies, asymptomatic patients show only slight decrements of the NPC over time while patients presenting symptoms show a significant recession of the NPC over time. Capobianco\(^23\) has noted that NPC will recede in the presence of a red lens over one eye. She thought that the degradation was a result of loss of voluntary convergence. However, this is incorrect since voluntary convergence is not stimulus bound. Furthermore, the red lens alters the fusible details by reducing the contrast of the target and by altering its color. Therefore, the recession of the NPC is most likely due to a loss in fusional convergence.

It is common to see head retraction, sweating, facial grimaces, and wrinkling of the fore-
head when the clinician performs the NPC. Mann" feels that these responses are indicative of neurotic tendencies. The author feel that they are, rather, indications of the amount of effort being exerted to force convergence of the eyes. For example two individuals show the same break on an NPC. One has forced the system to its maximum, while the other has relaxed convergence as soon as there is associated discomfort. Although both findings are normal and identical, the clinical picture is different. The individual who utilizes excessive effort will probably demonstrate symptomatology.

D. Near Point Analysis

Many authors have attempted to relate phoria (demand) to posi-


tive relative convergence. Landolt" felt that only one-third of the total convergence could be used at 33 cm and, therefore, 54 P.d. of convergence should be on reserve for maximum expenditure. Tait" said the reserves should equal twice the demand. Similar ratios have been reported by Neumuller" and Hofstetter." Despite the differences in numbers, all the authors agree that the reserves must be larger than the demand in order to avoid ocular fatigue. This method of analysis does not account for the amount of conscious effort used to overcome the introduction of BO prism which may radically affect reserves. Even though the analysis method incorporates both the phoria (demand) and BO fusional ranges (reserves), it does not provide an accurate means of predicting asthenopia since variables such as amount of time spent on near work, pain

threshold, and type of work are not considered.

E. Accommodation

Recently, accommodation has been implicated as a possible cause of CI. The Optometric Extension Program's method of analysis has theorized that accommodation is the cause of all non-classical CIs. (Classical CI includes low BO, receded NPC, exo at near, and low NRA.)

OEP has proposed that accommodation is a slower entity: that it mediates convergence; and that it is the last to develop phylogenetically. Therefore, it is more apt to break down under near point stress. Furthermore, they have noted that many CIs have been remedied solely with the application of plus lenses.

Accommodation, in a recent study by Prem Prakash et al. showed a reduction in 23% of the CIs. Von Noorden et al., Bugola and Raskind have also suggested that accommodation is the cause of CIs which do not respond to conventional convergence training. They advocate the prescription of plus lenses and BI prism.

The authors have noted that may CIs demonstrate reduced accommodative facility on the ± 2.00 D flipper test, low blur findings on vergence tests, and lowered amplitudes of accommodation. In addition, the treatment of CI with accommodative rock often results in improved BO to blur, BO to break, NPC and reduced exophoria at near. The latter is probably a result of a patient with a normal ACA ratio using the least amount of accommodation to maintain clear and single binocular vision. The patient places the proximal point of the depth of field at the plane of regard and, therefore, uses less accommodation. With training the patient is able to move his accommodation so that the center of the depth of field and the plane of regard coincide. Since there is a strong association between accommodation and convergence, convergence increases of the exophoria decreases.

There are also some CIs which result from accommodative fatigue. These may be remediated with the application of plus lenses for near. The accommodative effort, before lenses are applied, is too great for the system to handle. Here again the patient has used the least amount of accommodation and convergence possible for single, clear binocular vision. However, since the individual is at his/her physiologic limit, discomfort ensues. The addition of plus, therefore, reduces the accommodative load and makes it easier for the person to utilize the correct amount of accommodation to assist convergence. The person will usually report clearer and more comfortable binocular vision with the plus lenses.

F. Sensory Fusion

Worth" defined three grades of fusion: superimposition, flat fusion, and stereopsis. He felt that superimposition was the most rudimentary form, the easiest to demonstrate, and the last to disappear with the loss of binocularity. Stereopsis, on the other hand, was the most sophisticated form of binocular vision. Therefore, Worth felt stereopsis should be the first to disappear in the presence of binocular interference. His observations may have been correct for esotropia, but individuals with intermittent exotropia and normal binocular vision will show losses in grade 1 fusion (superimposition) before losses in stereopsis. The following people have normal binocularity, suppression represents a normal physiological process, eg. facultative suppression with a monocular microscope or a person's insensitivity to physiological diplopia. Also, suppression tests require suppression of the less dominant image, i.e., if a black target is presented to the right eye and a white background to the left eye in a stereoscope, the left eye must suppress the white background so that the black object is not seen in rivalry or differently than when monocularly viewed. In addition, retinal rivalry is a normal physiological phenomenon which requires alternate suppression because the brain cannot inte-
grate two totally dissimilar objects. Therefore, suppression is a normal physiological phenomenon.

On the other hand, the total loss of stereopsis has only been seen in patients demonstrating a constant strabismus, amblyopia, or some other major binocular anomaly. In fact, stereopsis may be a strong stimulus for binocular alignment of the eyes. It is entirely rare to find a CI who shows a decrement in stereoscopic acuity. The authors have only observed one CI who showed a complete absence of stereopsis. Suppressions, however, are common in CI, and probably serve as a sensory adaptation to eliminate diplopia and/or overlapping of fields, confusion and/or symptoms by creating functional monocularity. Therefore, the more severe the CI and the longer it has been manifest, the greater the probability of suppression with a resultant lack of symptoms.

It should be remembered that reading is one of the only instances where a person views a flat fusion stimulus. The loss of disparity cues in reading may not serve as a mechanism for suppression, but reading material itself may be a poorer stimulus for binocular alignment than stereo stimuli. Thus, therefore, may account for CIs experiencing symptoms while reading, but not while performing other near tasks.

G. Refractive Error
There is no correlation between refractive error and CI. Passmore and MacLean found 52% of their CI population was hyperopic, 34% myopic, and 14% was emmetropic. Smith attempted to correlate refractive error and CI in a population of 473 CIs. He found 38% were low myopes: 57% were emmetropes (1 D from Plano), and 5% were hyperopes (greater than 1 D). In another study, Hirsch found 61% of CIs had ametropia of .75 D or less. These figures are similar to the findings of refractive error in the normal population.

H. Relationship to Learning
Though the exact relationship of CI to learning has not been established, it has been implicated as a causative factor. Eames in studies comparing good readers to poor readers, found that CI was more prevalent in the group of poor readers. Similar findings have been reported by Park and Burr. The authors have observed numerous children who have demonstrated better attention, better concentration, less asthenopia and a better ability to sit and read after the remediation of a manifest CI. However, one must not assume that CI is the cause of learning disabilities nor responsible for severe learning problems. However, the authors have noted improved classroom performance of children after remediation of objective CI where no subjective symptoms have been manifest.

Etiology
Duke-Elder lists the following as causes of CI: wide interpupillary distance, delayed development or poorly developed accommodation or convergence, presbyopia, disease or debility which alters the metabolic state of the blood supply to the extraocular musculature, toxemia, endocrine disorders, and anxiety neurosis. Raskind said there are CIs secondary to systemic disorders which include: head trauma, encephalitis, drug intoxication, malnutrition, debility, hepatitis, and mononucleosis. The implication that CI is due to weak eye muscles or other mechanical difficulties has not been demonstrated. As a matter of fact, Davies has stated that the cause of CI is "not a question of weak eye muscles, but the result of a breakdown of the normal reflex action between accommodation and convergence." Davies also cites the following systemic causes of CI: sinusitis and/or dental infections.

Jampolsky feels that CI is most often the result of poor accommodation. The authors agree with Jampolsky, but caution that one must not ignore low positive fusional reserves in the treatment of CI.

Sasaki feels anemia is a significant cause of CI. He has described five types of anemia which may result in CI. These include:

a) atmospheric anoxia as found in high flying, mountain climbing, overcrowded rooms, and heat.

b) metabolic anoxia due to lack of vitamins, minerals, or amino acids which are necessary for respiration.

c) demand anoxia due to excessive work or stress.

d) oculoneurogenic anoxia

e) menstrual or pre-menstrual anoxia due to sympatheticotonia.

Sasaki has presented case reports of patients who as a result of heavy tobacco use, developed anoxia with a resultant CI and asthenopia. Elimination of tobacco use resulted in immediate recovery from the symptoms.

CI may rarely result from head trauma incurred in automobile accidents or gun shot wounds. According to Chandler these patients will respond to orthoptic treatment.

As stated earlier, other authors feel that CI is psychogenic. Only two authors have evaluated the relationship between psychological problems and CI. Mellick found that 76% of his sample of 63 CIs demonstrated neurotic tendencies. However, he does not discuss how he assessed or measured these neurotic tendencies. Furthermore, high correlations do not imply cause and effect. Mann in support of the psychogenic component, states that there are patients with CI,
but without symptoms, and that there are remediating CIs who still present symptoms. She concludes that since there is no correlation between signs and symptoms, CI must be psychogenic in nature. In the authors' opinions this is a naive approach since no one has yet evaluated the relationship of suppression, amount of effort, amount of near work, etc., with the manifestation of CI. Therefore, it would appear there is little evidence available to support the theory that CI patients with symptoms are neurotic. However, the authors have observed that "neurotic" patients often manifest symptoms to a greater degree than "non-neurotic" patients.

Another theory is developmental in nature. It is based on the premise that there are two types of convergence movements. One is an unconditioned reflex originating in the occipital lobe and responding to disparity or fusion. The other is a conditioned reflex and originates in the frontal lobe. The corrective eye movement for the fusional is believed to develop through experience by age five. Prior to this age accommodative convergence, voluntary convergence, and fusional convergence have not had enough experience to stimulate the psycho-optical reflex of convergence. Therefore, a lag in usage or in development will cause a convergence insufficiency. The difficulty with this theory is that with more sophisticated sensory testing with infants, it can be demonstrated that stereopsis, adequate visual acuity and convergence are all present within a few months after birth.

The authors feel that the breakdown in binocular vision is the result of a combination of factors and that these are the cause of ocular fatigue. Firstly, during near point tasks the eyes must maintain a constant and delicate balance between accommodation and convergence while performing close work. Thirdly, retinal disparity cues are absent during reading, making it more difficult for the eyes to maintain fusion. These three factors, in combination, may explain the ocular fatigue CIs experience if convergence is weak.

Most CIs present themselves without a known systemic or psychological cause. The CI may result from a breakdown of accommodative convergence, fusional convergence and/or voluntary convergence. It would seem that this breakdown would result in ocular fatigue with sustained near work. However, since the system is involuntary and the muscles are much stronger than they need to be to converge the eyes, there should theoretically be no ocular fatigue. However, there is!

Treatment
Almost 95% of the authorities cited in this paper state that CIs respond well to visual training or orthoptics, i.e., symptoms diminish and objective clinical findings improve. Table 1 lists the studies done to date.

Table 1 clearly illustrates the success with which CI can be remediating through vision training and orthoptics. These highly consistent findings are somewhat surprising in view of differences in treatment. Differences in definition of CI, differences in skills and motivation of therapists that exist between investigators. Most treatment programs were relatively short (5-11 visits) and therapists concentrated on building fusional, voluntary, and accommodative convergences. Some therapists used anti-suppression techniques, while others stressed jump ductions. Despite differences in treatment programs, 94% of patients treated showed relief of symptoms. Stutterheim and Mann have demonstrated improvements in visual acuity as a function of the elimination of small central suppressions. Many treated patients report improved concentration and retention. Passmore and MacLean noted that general tension disappeared and that their patients showed a positive change in personality. Another study reports that migraine headaches often ceased at the end of treatment of CI.

Mellick compared the results of treatment of CI between normals and diagnosed neurotics. He found 77% of his "neurotics" cured, 8% improved, and 14% without change. In the normal group, 78% were cured, 15% improved and 7% showed no improvement as a result of treatment. He concluded that there was no significant difference between groups.

The authors feel that treatment results may be enhanced by the use of monocular and binocular accommodative flexibility training, BO and BI range extension, jump ductions, voluntary convergence and sustaining of convergence or divergence while doing extended periods of near work, e.g. prism reader.

The authors have developed a training regimen for the treat-

| TABLE |
|--------|--------|--------|--------|--------|--------|
| AUTHOR | N      | CURED | IMPROVED | FAILED | DID NOT COMPLETE |
| Lyle & Jackson | 300 | 83% | 10% | 7% |
| Passmore & MacLean | 100 | 82% | 18% | 0% |
| Mellick | 88 | 77% | 10% | 12% |
| Mayou | 100 | 93% | 7% | 5% | 18% |
| Mayou | 87 | 92% | 6% | 2% |
| Mayou | 100 | 88% | 30% | 3% |
| Hirsch | 48 | 77% | 12% | 10% |
| Dutrie | 123 | 88% | 6% | 6% |
| Norn | 85 | 9.2% | 60% | 30% |
| Cushman & Burri | 80 | 86% | 30% | 4% |
| Wick | 134 | 93% | 4% | 3% |
| Hoffman et al | 17 | 94% | — | — |

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ment of CIs. They find that their rate of success is highest when training is broken down into the following phases:

a) Phase I — elimination of symptoms and normalization of accommodative and vergence functions.

b) Phase II — building excesses in the accommodation and vergences, i.e. +2.00 to −2.50 binocular flipper rock with suppression control, up to 50 p.d. of convergence and 20 p.d. of divergence at near.

c) anti-suppression and sustaining ability. Each phase should take approximately four visits when combined with home training.

Patients often notice worsening of symptoms during the first few weeks of training. Rarely, they may even vomit from the exercises. As long as the patient is informed that this may happen, no problems or unnecessary anxiety arises. Following this period of increased discomfort, most patients report that their symptoms disappear, concentration increases and near vision tasks are easier.

Since concentration and attention often improve as a result of therapy, CIs without subjective discomfort should also be treated. This is particularly true of children who have no reference point against which to gauge symptoms and, because of underdeveloped language skills, they have difficulty describing symptoms to parents and doctors. Since CI is more common in the learning disabled child, the authors feel that remediation, in the absence of asthenopia, is appropriate. The authors have seen many cases where symptoms, other than learning difficulties, have responded to treatment. However, dramatic changes occurred only in children who were experiencing lags in academic performance due to short attention span, poor concentration, inability to read for long periods of time, or poor retention. These are not the children manifesting severe learning disabilities.

Though most authorities agree that orthoptics or visual training is the treatment of choice there are some patients who do not respond to this form of therapy. One author11 who analyzed orthoptic failure in CI noted that 37% of these patients manifested a systemic component e.g. anemia or glandular dysfunction. It is also true that some patients resist vision training and may be given home training and/or prism therapy.

Prisms may relieve some of the symptoms, but are rarely as effective as training. Only one author12 advocates the use of prisms in all cases of CI. In his study, he presented three case studies which provided no controlled comparison. It should be remembered that prismatic lenses make the patient dependent upon a spectacle prescription. As mentioned above, prisms may always be utilized as a last resort. When necessary, the authors prescribe the least amount of prisms which eliminates an existing fixation disparity.

Hawksworth13 advocates the use of surgical intervention only when orthoptic therapy has failed. She performed surgery on a patient who had had orthoptic treatment at three different times and who experienced recurring symptoms each time. Hawksworth reported that following surgery the patient remained asymptomatic. It should be noted that the follow-up period was only two months. This is too short a time period to conclude the permanence of the success of the surgery.

The only other form of treatment of CI mentioned in the literature is miotic therapy. However, Von Noorden et al12 observed that in his experience miotics only increase the exophoria and the discomfort of CI patients, and are therefore contraindicated.

Summary
CI patients have reduced convergence which manifests itself through lowered NPC, PFR, NRA, convergence activities. These patients may or may not manifest symptoms. The presence of symptoms in CI is dependent upon the amount and type of near work, degree of suppression and sensitivity to pain. Vision training as a mode of therapy in CI has been shown to be extremely effective. Effectiveness of therapy is judged by relief of symptoms, improvement of concentration and reading skills, and improved accommodative and vergence abilities. AOA

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