Myopia and Accommodative Insufficiency Associated with Moderate Head Trauma

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ABSTRACT

Background: Brain injury as a result of moderate head trauma may result in the development of myopia and significant accommodative dysfunction for individuals who previously had no history of myopia prior to the head trauma. This combination of visual changes has not been studied to any significant degree.

Methods: The records of fifteen patients with a history of moderate traumatic brain injury (TBI) that resulted in myopia and accommodative insufficiency, but with no prior history of myopia nor strabismus, were reviewed retrospectively. Information regarding age, sex, distance refraction and near vision function was assessed.

Results: The majority of subjects reviewed had developed a stable degree of myopia between 1.00 and 2.00 diopters, as well as an abnormally high lag of accommodation. When their distance and near spatial area of focus was compared, the majority were focused at an intermediate area in space, suggesting a loss of control of accommodation in space.

Conclusions: A model to explain the results was formulated, and the implications for vision care discussed. Further research is necessary with larger study numbers to confirm these results and to further test the hypothesis that TBI can cause a loss of spatial control of accommodation, with accommodation tending to localize at the individual's dark focus.

Keywords: accommodation, acquired myopia, dark focus, head trauma, moderate brain injury

Introduction

Moderate traumatic brain injury is defined as having an initial Glasgow Coma Scale score between 9-12, with loss of consciousness lasting minutes to hours, and long lasting or permanent physical and cognitive impairments.[1,2] Traumatic brain injury (TBI), especially of a moderate to severe degree, commonly results in significant ocular and visual problems.[3,4,5]

Almost all studies concerning the visual effects of TBI report a high incidence of "blurred vision", although frequently the reports do not differentiate as to whether vision is blurred at distance, near or both. These reports also do not provide clear diagnoses of the visual dysfunctions responsible for the complaints of blurred vision.[6,7,8]

One of the most commonly affected visual functions is accommodation,[6,9] which involves the ability to maintain accurate, clear and comfortable focus on a visually fixated object at a certain distance, as well as the ability to quickly and accurately change focus from one object of regard to another object at a different location in space. Gianutsos et al. found 69% of one study group of 55 severely brain-damaged patients had significant accommodative insufficiency,[6] while Suchoff et al. reported almost 10% of 62 patients with traumatic brain injury had accommodative dysfunction.[10] Interestingly, in the latter study, the authors comment that "…approximately 50% of … (all) subjects needed glasses for the first time, a replacement for lost glasses, or a change of prescription", without specifically giving the reasons for glasses.

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Kowal, in a neuro-ophthalmological study of 161 patients with head trauma, reported 16% had poor accommodation and 19% had pseudomyopia, which persisted for six months or more in 58% and 55% respectively.[11] He found that, "treatments using cycloplegics with sunglasses and bifocals were … uniformly rejected by patients…". Both Kowal and London[12] found the "excess" accommodation disappeared with cycloplegia, but commonly recurred as the effects of cycloplegia disappeared.

The diagnosis of myopia in a patient following TBI, with no pre-existing myopia, is not uncommonly encountered in clinical practice by optometrists who examine significant numbers of such patients, but the magnitude of the myopia following acquired brain injury has not been extensively studied. Accommodative insufficiency is very common in subjects with a history of moderate TBI, and has had more extensive coverage.[13,14,15,16,17] The coexistence of myopia and accommodative dysfunction in some patients who have suffered TBI has not been previously investigated to determine the magnitudes and patterns of myopia and accommodative dysfunction. Similarly, no model has been postulated to provide a basis for understanding an apparently coincidental combination of these visual dysfunctions.

Methods

The first fifteen clinical records of patients selected randomly from our optometric practice record system, where the patient had a history of TBI and subsequent myopia and abnormal lag of accommodative, were analyzed for measurements of right eye distance refraction and right eye near accommodative response and locus. Selected subjects must have had:

1. No history of pre-trauma myopia (as ascertained by reliable history and/or consultation with previous eye care providers)
2. A history of moderate TBI
3. Post-traumatic acquired myopia
4. Abnormal lag of accommodation
5. No ocular pathology (other than possible mild optic atrophy)
6. No strabismus

Not all patients with a history of TBI develop acquired myopia. This study was directed at describing the characteristics of the set of people who developed myopia, together with an abnormal lag of accommodation, following TBI. The 15 records selected included subjects within an age range from 21 years to 43 years (mean 29 years), with 13 males, and 2 females.

Monocular Estimate Method (MEM) retinoscopy was performed with the subject reading aloud a sequence of letters on a target attached to a retinoscope at 40 cm. Lenses of a lens rack were interposed very briefly before each eye in turn to determine the plus power which neutralized reflex movement.

Data were extracted for patient age, right and left eye sphere refraction, and right and left eye near retinoscopy result (MEM). Refraction was performed by retinoscopy of each eye, with the subject viewing an animated target at 6 meters; fixation was monitored by an assistant. Cycloplegia was not used for distance retinoscopy. The distance in space from the subject where distance or near focus was located was calculated as follows: Distance refraction spatial locus in centimeters (cm) = 100 / spherical result in diopters (D); near refraction spatial locus (cm) = 100 / (2.5 - near accommodative lag (D))

Given a visual demand of 2.5 diopters at 40 cm, the actual accommodative response of each visual system can be calculated by subtracting the lag in diopters from the demand in diopters. For example, a lag of accommodation of 1.00 diopter means an accommodative response of 1.50 diopters (2.50-1.00), which indicates the visual system is actually focused at 66 cm (100/1.5).

Results

The results of data analysis are tabulated in Table 1.

The results of right eye myopia measured for the 15 cases are detailed in Figure 1, and range from -0.75 D to -2.25 D (mean 1.22 D, +/-0.62). Of the 15 cases analyzed for myopia, 13 (87%) had a refractive status between -0.50 and -1.50. One subject had a monocular astigmatic measurement of 0.50 D, and another subject had a monocular astigmatic measurement of 1.00 D.

The patients' visual systems, when required to attend at a testing distance of 6 meters during distance retinoscopy and refraction, localized closer than the distance visual demand, an actual lead of visual response, despite an absence in all cases of pre-trauma myopia. In visual-spatial terms, the visual system, although viewing a distance target, focused in space within a range of 33-133 cm from the patient (mean 95 cm, +/- 30.7 cm) (see Fig 2).

Table 1: Subject data

Subject	Age	RE sph (D)	RE spatial (cms)	LE sph (D)	LE spatial (cms)	MEM lag(D)	MEM spatial (cms)	Difference (cms)
1	23	-0.75	133	-1	100	2	200	67
2	41	-1	100	-1.25	80	1.5	100	0
3	43	-1	100	-1.25	80	1	67	-33
4	33	-1	100	-1	100	1.5	100	0
5	38	-1.25	80	-1.25	80	1.5	100	20
6	21	-2.25	44	02.25	44	1.25	80	36
7	24	-3	33	-3.5	29	-.5	50	17
8	24	-0.75	133	-1.25	80	1.25	80	-53
9	23	-1	100	-1	100	1.5	100	0
10	33	-1	100	-1.25	80	1.75	133	33
11	22	-0.75	133	-1	100	1.75	133	0
12	28	-1.25	80	-1.25	80	1.25	80	0
13	30	-1.25	80	-1.5	67	1.25	80	0
14	28	-0.75	133	-1	100	-0.25	36	-97
15	30	-1.25	80	-1.25	80	-.5	50	-30

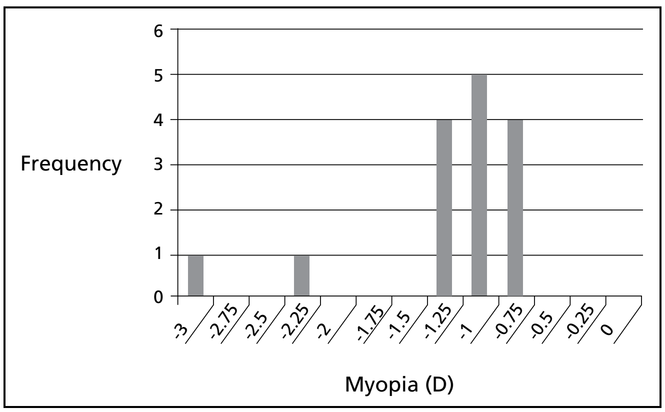

Figure 1: *Distance refraction myopia (D) N=15*

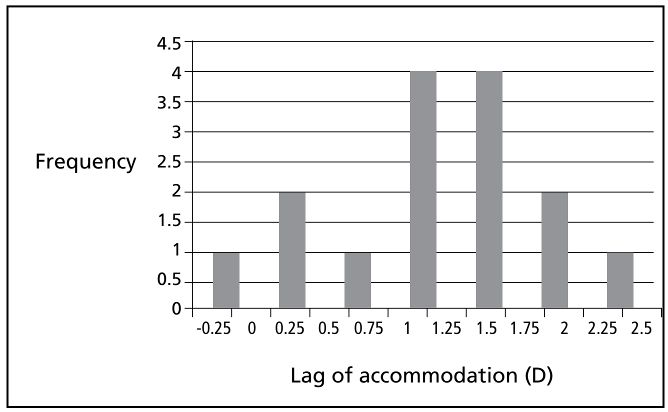

Figure 3: *Lag of accommodation at 40 cms (D) N=15*

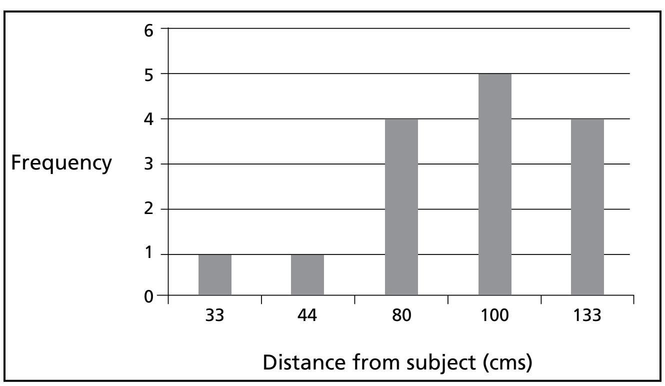

Figure 2: *Spatial localisation of distance refraction (cms) N=15*

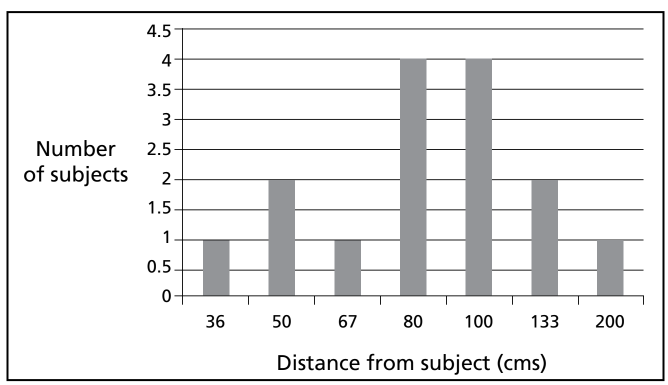

Figure 4: *Spatial locus of accommodative response for 40 cms target N=15*

Similarly, the patients' accommodative systems, when tested with a near visual demand at 40cm, responded by focusing significantly further away in space than the target, resulting in a lag of accommodation. In only one case was there a lead of accommodation, or the accommodative response resulting in a focus closer than the target of -0.25 diopters. The range of accommodative responses varied between 2.00 and 0.50 diopters (mean +1.22 D, +/-0.58) (see Figure 3). Objective measurement of near accommodative response to a target at 40 cm by MEM retinoscopy indicated a lag of accommodation between 1.00 and 2.00 diopters in 12 of 15 cases (80%). The accommodative response was within a spatial range of 36-200 cm from the subjects (see Figure 4). If the locus of accommodation of each case is calculated in this way, of the 15 patients studied 11 of 15 (73%) had an accommodative near locus between 60 and 100 cm from the patient.

To analyze the relative position in space of each visual system when tested at distance and near, the respective localizations can be subtracted from each other. For comparison the distance spatial locus was subtracted from the near spatial locus to analyze the disparity. A positive result indicates the near visual response is further in space from the patient than the distance response, and a negative result indicates the response of the visual system when tested at distance is actually localizing further in space than the response when tested at near, as is expected in normal visual function.

For example, in Case 4 the 33 year old male had a right eye distance refraction of -1.00 sphere (focused at 100 cm), and a lag of accommodation of 1.50 diopters when measured at 40 cm (focused at 100 cm); the resultant difference is 0 cm, indicating the visual system in this case is focused at exactly the same place in space, when tested with a distance (6m) target or a near (40 cm) visual demand.

Similarly, in Case 5 the 38 year old male measured right eye myopia of -1.25 sphere (80 cm), and a lag of accommodation of 1.50 D (100 cm), with a difference in visual response of 20 cm. In Case 8 the 24 year old subject had a right eye distance refraction of -0.75 (133 cm) and a near lag of accommodation of +1.25 D (80 cm), indicating a difference of -53 cm.

Analyzing the difference in response in space of each visual system for distance and near targets, the average subject focus at distance and near was within 3 cm of each other, although there was significant individual variation (mean -3 cm, +/- 39.3cm) (see Figure 5). Of the 15 cases, 12 (67%) responded by localizing at exactly the same distance from the person or within 25 cm of the other visual response. Similarly, 13 of 15 (87%) of cases showed localization in space, of distance and near vision responses, within 50 cm of each other. All of the 15 cases demonstrated a spatial response of vision, when tested at distance and near, within 75 cm of each other.

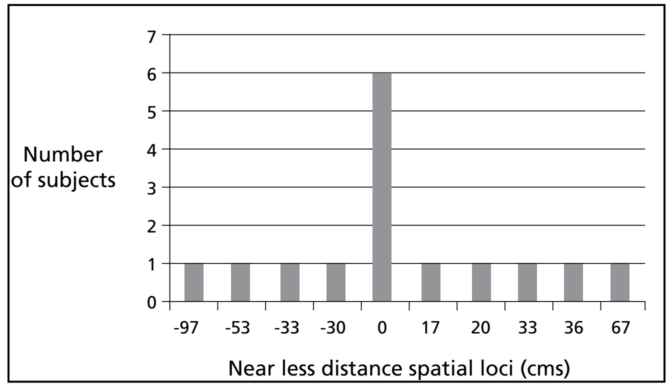

Figure 5: *Difference of spatial loci of near and distance focus (cms) N=15*

Discussion

The 15 cases studied were selected because each subject had developed myopia associated with TBI, and yet had no history of pre-trauma myopia. In spatial terms, when they were refracted while viewing a 6 meter target, they had a habitual focus closer in space than the visual demand.

Monocular Estimate Method (MEM) retinoscopy has been shown to be a valid and reliable measure of the accommodative response to target stimulus demand.[18,19,20] Normative data for the lag of accommodation in normal populations indicates that accommodative response is expected to lag behind the stimulus plane by between 0.25 and 0.75 of a diopter.[21,22,23] As such, the accommodative response to a target at 40 cm, a demand of 2.5 diopters, will generally be between 2.25 and 1.75 diopters. Essentially, the person will be focusing between 44 and 57 cm away, for a target at 40 cm.

Of the subjects assessed using near retinoscopy, 14 of 15 subjects demonstrated a significant under – accommodation when tested while viewing a 40 cm near target, an abnormal lag of accommodation. While a small lag of accommodation for near visual tasks has been shown to be physiologically normal,[24,25] the majority of subjects showed an abnormally high lag of accommodation, indicating an inadequate response of accommodation to a near visual demand. Spatially, almost every subject focused much further away than the test target. The majority of near accommodative responses to a 40 cm test target was to localize between 60 and 100 cm from the patient. No history is available as to the existence of pre-trauma accommodative dysfunctions in these patients, so it is possible that some of the accommodative dysfunctions measured were pre-existing. However, the degree of accommodative dysfunction in most cases is abnormally high.

When the difference (in cm) between each subject's visual response to near and distance targets was calculated, the most common response (6/15) of the identification system, supposedly viewing a distance or a near target, was to localize in the same place in space between 80 and 100 cm from the patient. This could be described in regard to distance viewing as accommodative excess, but the increased accommodation is only manifest at distance, and not at near.

This excessive focus for distance targets has been labeled pseudomyopia.[11] As in past studies, this label is dependent on a finding of blurred vision at distance improved by a myopic correction, when cycloplegic refraction showed less myopia or even hyperopia.

Suchoff and Petito have defined accommodative spasm as a pattern of greater accommodative response than normal for a particular accommodative demand.[26] The characteristics of myopia diagnosed in people with head injury is at times confused in the literature with spasm of accommodation and spasm of the near reflex.[27,28] The terminology is described by Scheiman and Wick, who suggest the term accommodative excess should be used for the pattern described by Suchoff and Petito, with spasm of the near reflex confined to the more severe form of spasm of accommodation associated with miosis and esotropia.[29] As Kowal and London have shown, cycloplegia temporarily eliminates the apparent myopia[11,12] in subjects with a history of TBI, consistent with a diagnosis of pseudomyopia.[30] Accordingly, all the subjects in this study can be described as having pseudomyopia but certainly 14 of 15 studied do not have accommodative excess.

The visual systems in question appear to have significant difficulty responding to differences in target spatial demand, or focusing further than this area for a 6 meter test chart or focusing closer for a 40 cm near test chart. An interpretation of this pattern of visual response may be that, following TBI in young adults, their visual identification systems (involving accommodation) may become localized approximately 80 to 100 cm away, and be unable to accurately respond by focusing outwards to distance objects, or inwards to near objects. This lack of spatial change of the visual system can be described as being "stuck in space" approximately 80 to 100 cm away (as portrayed in Figure 6).

It is generally accepted that without a visual stimulus, the accommodative response is usually between 0.5 and 1.5 of a diopter.[31,32] Dark focus, the area in space from the subject where the visual system localizes in the absence of visual stimuli (dark, ganzfeld) has been postulated to be a fulcrum around which accommodative response varies, outwards for a distance stimulus and inwards for a near target.[33] The accommodation system, in the absence of visual demand, adopts a resting focus of approximately 1 diopter, thus localizing in space about 1 meter away.[34] Dark focus varies individually,[35] and can change gradually over time. The dark focus is generally considered to be about 80-100 cm from an individual, and the visual systems of the subjects in this study also tend to localize approximately in the same area.

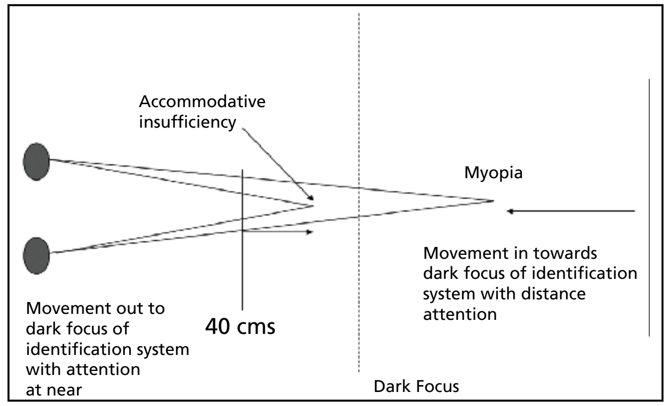

Figure 6: *Spatial changes of the identification system (accommodation) for distance and near targets following severe head trauma*

Wachs has characterized accommodation as a "sensorimotor intelligence," a developed ability to posture accommodation at different distances from the person, to provide clear vision as a means of visual identification, or in his words a "self-directed, intrinsically constructed knowledge of body, physical world and practical use."[36] This "learning" of where to focus in space occurs through movement in the spatial world of a child by reaching for an object or with body movement.

One hypothesis which could provide a rationale for understanding the development of myopia following head trauma, together with accommodative insufficiency, is as follows:

1. Brain injury as a result of TBI can disrupt a person's ability to access learned sensorimotor control of accommodation in visual space along the spatial axis outwards from the body.
2. The accommodation system loses its ability to know how to accurately respond to changes in task distance.
3. The accommodation system essentially localizes at its resting tonus i.e. dark focus.
4. Testing at distance shows myopia.
5. Testing at near shows accommodative lag.

6. Long term, the visual system adapts to this new "learned" operation, unless the system is retrained at an early, more plastic stage.

London[12] describes three patterns of post- head trauma myopia:

1. Transient cases which resolve
2. Chronic but stable, most common
3. Progressive myopia, less common

Patients in the initial stages of developing a pattern of post-trauma myopia and accommodative insufficiency (London's Type 1) may infrequently present early to optometrists for care, as their acute medical care takes precedence over transient and often unrecognized visual dysfunctions. It is only much later in rehabilitation when a visual problem may be recognized by other rehabilitation professionals, or the subject is sufficiently aware and communicative of a visual blur at distance and/or near, that optometric care may be sought.

If the model of post-head- trauma myopia resulting from a breakdown of learned visuo-spatial control of accommodation is accepted as feasible, then it should be possible to provide vision therapy to relearn spatial control of accommodation. Subjects with this syndrome of post trauma myopia and accommodation dysfunction often appear to demonstrate severe difficulty with accurate monocularly directed finger touching of a small target (Wolff wand) held within arm's reach. This suggests a breakdown in proximal judgment of position in space.

Optometric vision therapy has been shown to be effective in treating accommodative dysfunctions in the normal population.[37,38,39] To date no large studies have been published of treatment with vision therapy of accommodative dysfunctions in patients with traumatic brain injury, but clinical case reports have indicated vision therapy is effective in improving accommodative function in patients with TBI.[40,41,42]

Using the model outlined, where apparent myopia is found to occur shortly following a traumatic brain injury, it could be managed by optometric vision therapy of accommodation, emphasizing change in space supported by proprioceptive involvement, together with sufficient plus at near to minimize near visual stress. It may be possible to relearn the visual-spatial skill of focusing while the visual system is still unstable, although this will depend on the degree of head injury and brain structures damaged, as well as the cognitive and communication skills of the patient.

When a person diagnosed with acquired post-traumatic pseudomyopia is considered relatively stable in general recovery and periodic examination shows no significant increase in apparent myopia, the visual dysfunction may be managed by:

1. Minus at distance if required on consideration of patient needs and concerns
2. Plus at near
3. Optometric vision therapy if there is motivation and ability to reduce the visual dysfunctions

However, in chronic cases the patient may have essentially rebuilt their visual space around the adaptation, and it may be very difficult to access and normalize the impaired sensorimotor knowledge of operation of the accommodation system in space.

In cases where the degree of acquired post-traumatic myopia is found on repeated examination to be increasing, it can be postulated the patient's adaptation of visual space is not "working" for them. Therefore, it continues to build as in a person with progressive myopia, increasing apparent myopia and reducing accommodative lag to an eventual lead of accommodation.

Conclusions

The combination of the development of myopia and accommodative insufficiency in people who have no history of myopia prior to suffering a TBI is commonly encountered by optometrists experienced in rehabilitative vision care. The apparently coincidental visual dysfunctions at distance and near both produce blurred vision, but may in fact be connected as features of a breakdown of visual spatial control of accommodation and vergence.

It is important to comprehensively assess near accommodative function in patients with a history of TBI, and to relate it to distance visual function. The information gained can provide valuable insights into the effects of vision on activities of daily living, progress in rehabilitation, prognosis for stability and improvement or further deterioration of visual function. Certainly the optometric use of lenses, prisms, and optometric vision therapy to re-develop, or at least to stabilize adapted visual spatial judgment, should be implemented when indicated.

This study involved a small numbers of subjects. I suggest that a larger study be developed to assess myopia and significant accommodative dysfunction in the TBI patient, as well as to relate measurements of myopia and accommodative function to clinically measured individual dark focus. The theoretical model proposed above that provides a rationale for the development of myopia and accommodative inaccuracy requires further analysis and development.

However, despite the small numbers studied, the data suggests people who experience a traumatic head injury, resulting in moderate brain injury, and who subsequently develop moderate myopia and significant accommodative insufficiency, may have impairment of learned spatial control of accommodation for viewing distance and near targets. Management should involve the use of minus lenses to provide clear distance vision, plus lenses to assist clear focus for near visual demands, and possible optometric vision therapy to develop more accurate control of focus in space.

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