Kenneth J. Ciuffreda, O.D., Ph.D., and Diana P. Ludlam

Objective diagnostic and interventional vision test protocol for the mild traumatic brain injury population

The "signature" injury of the recent military encounters in Iraq and Afghanistan is traumatic brain injury (TBI).[1] Approximately 30% of the returning war fighters have a TBI in one of these categories: mild, moderate, or severe.[1] Such TBIs produce a constellation of deficits of a sensory, motor, perceptual, cognitive, behavioral, and/or attentional nature,[2] including residual vision-based sequelae.[3,4] These frequently include oculomotor and accommodative abnormalities, spatial mislocalization, visual-vestibular integrative dysfunction, visual field loss, photosensitivity, visual motion sensitivity, visual attentional problems, and visual perceptual deficits/processing problems.[2-6] This is true for both military and civilian populations with TBIs.[2-4]

One of the additional challenges involved in the visual testing and diagnosis of individuals with TBIs is the presence of a cognitive impairment; in fact, this is a priority area for the military.[7] Presence of such a constellation of vision problems in combination with a cognitive deficit makes the diagnostic assessment even more difficult and less reliable. For example, the clinician may attempt to conduct a traditional comprehensive battery of optometric vision tests in a routine manner, such as visual field testing and Maddox rod phoria assessment, in such a patient. However, when there is a fixational instability and a cognitive dysfunction, the patient may be unable to respond readily to these standard and important clinical tests. Presence of this fixational anomaly would increase response variability, whereas the concomitant cognitive defect would decrease response reliability. This notion might also apply to routine refractive procedures, e.g., "Which is better, 1 or 2?" To such an apparently simple query, the TBI patient can exhibit slowed and tentative responses, frequently requiring many repetitions, thus confounding and perhaps even invalidating the findings. This can lead to frustration for both the patient and doctor. Furthermore, the TBI patient can be overwhelmed easily by having too many choices and therefore have difficulty expressing responses clearly and accurately. Finally, these patients can be fatigued easily and might be unable to endure extended testing as routinely conducted and tolerated by the non-TBI patient.

One manner in which to circumvent, or at least minimize, such potentially serious problems is with the use of objective testing that does not rely on verbal responses or subjective impressions of the patient. In addition to circumventing the possible adverse and contaminating effects of a concomitant cognitive impairment, the proposed objective protocols are immune to placebo influences or malingering. For example, one cannot "will" a slowed saccade or vergence response nor "inhibit" the response to the visual stimulus recorded during either a visual-evoked response (VER) or electroretinography test. Hence, these proposed protocols can be applied before and after active military duty to document ocular or visual dysfunctions sustained during this period. Furthermore, these proposed protocols can also be applied to document ocular and/or visual improvements after therapeutic intervention.

Therefore, we propose comprehensive, objective vision-based diagnostic and interventional test protocols for use in the TBI population, in particular for the individual with a mild TBI (mTBI) for whom the various laboratory and

Kenneth J. Ciuffreda, O.D., Ph.D.

Diana P. Ludlam

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clinical test situations can be more easily adapted. In fact, most of the proposed procedures and measures are appropriate for either the clinical research laboratory or hospital facility. However, some can be done in the clinical optometric office setting (e.g., computerized corneal topography and optical coherence tomography) as well. Each parameter of the protocols contains a number of related and specific subparameters to be tested. These have been determined based on considerable clinical and laboratory testing by our group and others or from suggestions in the literature, as listed below. They have either demonstrated or predicted abnormality and thus would have "high yield" with few false-positive results in the mTBI population. These parameters and subparameters will be listed with brief global explanations and selected key references.

Test protocols

Table 1 presents a detailed listing of the main oculomotor-based vision parameters and subparameters, which we believe represents a critical set of functional components that can be assessed objectively with a resultant high yield of abnormalities. This includes both static and dynamic components for each oculomotor subsystem, namely vergence, accommodation, and version, as well as the related systems of the pupil and visuomotor posture.[2,4,8-10] All of these oculomotor-based visual systems can be assessed objectively using commercially available ophthalmic equipment (e.g., the WAM-5500 [for accommodation]; AIT Industries, Bensenville, Illinois, and the Visagraph [for reading eye movements]; Bernell, Mishawaka, Indiana) or, in some cases, requiring simple computer software development for analysis.

Table 2 presents a detailed listing of the main nonoculomotor-based vision parameters and subparameters, which we again believe represents a critical set of functional components that can be objectively assessed with a resultant high yield of potential abnormalities. These include psychophysical, electrophysiologic, and anatomic testing of primarily the afferent visual pathways at all levels.[2,10-12] All of these areas can be assessed objectively using commercially available ophthalmic equipment (e.g., the Diopsys NOVA-TR system [for VER]; Diopsys, Pine Brook, New Jersey, and the Advanced Therapy Systems RT-2S [for reaction time]; Advanced Therapy Products, Glen Allen, Virginia) or, in some cases, requiring simple computer software development for analysis.

Table 1 Oculomotor-based objective diagnostic and interventional vision test protocol

- Vergence
  - Peak velocity
  - Time constant
  - Latency
  - Steady-state variability
  - Distance and near horizontal and vertical phoria
  - Stimulus AC/A ratio
  - Near point of convergence
  - Vergence ranges at near
- Accommodation
  - Peak velocity
  - Time constant
  - Latency
  - Steady-state variability
  - Fatigue induction
  - Maximum amplitude
- Version
  - Fixational variability
  - Saccadic gain
  - Pursuit gain
  - Vestibular-ocular reflex gain
  - Optokinetic nystagmus gain
- Reading eye movements
  - Baseline grade level
  - Reading rate
  - Number of progressions
  - Number of regressions
  - Single-line simulated reading saccade ratio
- Pupil
  - Peak velocity
  - Time constant
  - Maximum amplitude
  - Steady-state variability
  - Latency
  - Steady-state amplitude
- Dynamic posturography
  - Posture and gait analysis
  - Center of gravity

Table 2 Nonoculomotor-based objective diagnostic vision test protocol

- Open-field autorefraction with combined keratometry
  - Sphere
  - Cylinder and axis
  - Keratometric readings
- Computerized corneal topography
  - Dioptric mapping
  - Surface regularity
- Electroretinography
  - a-wave amplitude
  - b-wave amplitude
- Retinal and ocular imaging
  - Optical coherence tomography
  - OPTOS® retinal map
- Visual-evoked response
  - P100 latency
  - P100 amplitude
  - Alpha attentional component
- Brain imaging
  - Diffuse tensor imaging
  - Functional magnetic resonance imaging
- Reaction time
  - Eye-hand
  - Eye-foot
- Intraocular pressure

Table 3 presents a prioritized, 2-tiered, and "streamlined" protocol encompassing both oculomotor-based and nonoculomotor-based aspects derived from Tables 1 and 2. Fifteen key parameters are specified. The first 6 (asterisks) have the highest yield and are the most sensitive tests if assessment time is limited (e.g., 15 minutes).[4,5,8-11] However, if possible, all 15 parameters of the abbreviated protocol should be tested. And, if one is forced to select only a single, high-yield parameter, it would be peak velocity of the respective system.[4,9]

Therapeutic intervention

Once the described objective testing is performed to the degree needed and possible within the individual clinical facility, the information obtained can be used in conjunction with other nonobjective clinical test findings, if any, and the appropriate diagnoses can

Table 3 Streamlined objective diagnostic vision test protocol

- Vergence peak velocity*
- Accommodative peak velocity*
- Single-line simulated reading saccade ratio*
- Near point of convergence*
- Accommodative amplitude*
- Optical coherence tomography*
- Computerized corneal topography
- Fixational instability
- Saccadic gain
- Reading rate
- Pupil peak velocity
- Brain imaging
- Visual-evoked response amplitude and latency
- Visual-evoked response alpha component
- Eye-hand reaction time

*Have the highest yield and are the most sensitive tests if assessment time is limited (e.g., 15 minutes).

be established. Then, the targeted therapeutic interventions, both optometric and medical, can be implemented.[5,6] Furthermore, all aspects of the proposed protocols may also be used to assess therapeutic efficacy. Such targeted, objective assessment should lead to a more rapid integration of the individual with mTBI into society for successful attainment of their vocational and avocational goals.

Conclusions

Both comprehensive and streamlined vision-based objective test protocols have been proposed for an individual with mTBI and residual vision problems. These are particularly important in the face of coexisting cognitive impairments that many such individuals experience, which both compounds and confounds the basic vision examination and its interpretation. With more focused and targeted objective diagnostic test protocols, the treatment protocols likewise will become more focused, rapid, and streamlined. The result will be more efficient and optimal care for the visually symptomatic patient with TBI. In addition, the proposed protocols can be used to assess therapeutic efficacy as well as to document any injury to the visual system believed to be sustained during active duty in the military.

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Corresponding author:

Kenneth J. Ciuffreda, O.D., Ph.D.,
State University of New York
State College of Optometry
Department of Vision Sciences,
33 West 42nd Street,
New York, New York, 10036.