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Screening Scale of Oculomotor Symptoms in Traumatic Brain Injury Patients to Facilitate Referrals to Neuro-Ophthalmologists for Rehabilitation

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Abstract

***Background**: Oculomotor dysfunction (OMD) is observed in perhaps 10% to 30% of motorists injured in high impact car accidents. A screening tool for signs of OMD is needed to facilitate systematic evaluations of such patients for potential referral to neuro-ophthalmologists for rehabilitation.*

***Method**: A perusal of neuro-opthalmological case reports and OMD literature led to the development of a 15 item scale. This Oculomotor Scale was administered to 29 survivors of high impact motor vehicle accidents (MVAs) who complained about OMD signs and to 30 normal controls. The patients' scores were also available on the Rivermead measure of the post-concussion syndrome, the Post-MVA Neurological Symptoms (PMNS) scale, the Insomnia Severity Index, and ratings of pain, depression, and anxiety.*

***Results**: Criterion validity of the Oculomotor Scale is demonstrated by its very satisfactory capacity to differentiate the patients reporting OMD signs from the normal controls (point biserial coefficient =.87, p<.001). Convergent validity of the scale is shown by its significant and large correlations to Rivermead post-concussive scores (r=.70, p<.001) and to the PMNS measure of post-accident neuropsychological symptoms (r=.65, p<.001).*

***Discussion and Conclusions**: The Oculomotor Scale has not been designed for independent diagnosing of oculomotor dysfunction (OMD): it is intended only as a brief screening scale for family physicians or medical psychologists, in order to facilitate a referral for the thorough professional assessment by specialized rehabilitative neuro-ophthalmologists. Hopefully, the availability of this screening scale would increase the number of referrals of such patients with post-accident oculomotor dysfunction for beneficial specialized assessment and therapies by rehabilitative neuro-ophthalmologists.*

Keywords: *oculomotor dysfunction, visual tracking, oculomotor scale, post-concussion syndrome, whiplash syndrome*

Introduction

Embryologically the eyes are developed as an extension of the brain which is enclosed in the rigid cranium where it is cushioned by the cerebrospinal fluid. Any blow or violent shakes to the head or upper body, as do occur in road traffic accidents, usually affect the brain functions which may present with concussion. Symptoms of concussions may be subtle or intense. When symptoms persist beyond about three weeks, they are referred to as post-concussion syndrome.

The eyes facilitate visual environmental scanning necessary for maintaining balance and coordination. Traumatic brain injury usually disrupts these visual functions. Patients may then present with varying degrees of occult-motor dysfunctions, OMD. Early rehabilitation of these dysfunctions is essential for improved quality of life in patients with traumatic brain injuries. Voluntary or involuntary visual scanning are mediated by cranial nerves and muscles. Disconjugate eye movements can result from traumatic brain injury affecting vision and control of eye movements. Ocular motility dysfunction may be associated with significant visual problems. Injured motorists who display various signs of the post-concussion syndrome as well as severe problems with visual tracking of moving objects, or difficulties focusing on printed texts, could often benefit from assessment and treatment by specialized rehabilitative neuro-ophthalmology services.

As explained by Strupp et al. (2014), neuro-ophthalmological assessments include "*a systematic clinical examination of the different types of eye movements, including: eye position, range of eye movements, smooth pursuit, saccades, gaze-holding function and optokinetic nystagmus, as well as testing for the different types of nystagmus (e.g., central fixation nystagmus or peripheral vestibular nystagmus)*."

Vestibular-ocular symptoms have been recently documented in young athletes in the context of post-concussion syndrome and related neuropsychological impairments (see Sinnott et al., 2019). These CNS injuries occurred while participating in sports such as soccer, basketball, football, and hockey.

Differential diagnosis is important because oculomotor dysfunction can also occur in various progressive neurological diseases such as Parkinson's disease, amyotrophic lateral sclerosis, etc. (see Strupp et al., 2014) or sometimes in reaction to external causes such as chemotherapy.

A recent study by Rockswold's team (2019) of functional MRI of patients with mild traumatic brain injury (mTBI) and oculomotor dysfunction (OMD) provided evidence that "*neural networks of interaction involving the control of eye movement for visual processing, reading comprehension, spatial localization and navigation, and spatial working memory ..... are affected in mTBI patients with OMD compared with mTBI patients without OMD*."

In our clinical work, signs of oculomotor dysfunction were reported to us by approximately 10% to 30% of patients with documented post-concussion syndrome following high impact motor vehicle accidents (MVAs). Such patients warrant attention by specialized neuro-ophthalmologists. The practical problem encountered by frontline general physicians faced with such clinical situations is how to identify patients with OMD for referral.

The present study describes the development and psychometric characteristics of a screening scale for assessment of OMD. This screening scale would evaluate systematically the presence of relevant oculomotor symptoms thereby generating a document based on objective findings and patient's self-reports. This document could be forwarded to the neuro-ophthalmology services as part of the referral package for consideration of rehabilitation.

Method

OMD Questionnaire

On the basis of a perusal of neuro-ophthalmological assessment reports and of recent publications on OMD, we prepared a list of 15 items to comprise the Oculomotor Scale, see the text in Table 1. We requested that patients evaluate their symptoms on a scale from 0=no difficulty to 10=severe difficulty.

Table1. *Oculomotor Scale*

For each item below, please rate how difficult it is for you since your accident on a scale from 0 (no problem) to 10 (severe difficulty).											
Since the accident, I have more difficulties	0= ***no difficulty***										10=***severe difficulty***
1. To follow with my eyes a moving object such as a car, a flying bird, or running person.	0	1	2	3	4	5	6	7	8	9	10
2. Watching a movie because it triggers or worsens my headaches.	0	1	2	3	4	5	6	7	8	9	10
3. Watching a ball game and following the ball with my eyes.	0	1	2	3	4	5	6	7	8	9	10
4. Locating small food items or small food containers in the fridge.	0	1	2	3	4	5	6	7	8	9	10
5. Recognizing some simple facial expression of actors in a video.	0	1	2	3	4	5	6	7	8	9	10
6. Recognizing friends from the distance that previously would cause no such problem.	0	1	2	3	4	5	6	7	8	9	10
Since the accident, reading causes me the following problems											
7. The words seem to "jump around" or change their location on the page.	0	1	2	3	4	5	6	7	8	9	10
8. It is now more difficult to focus on each word without it seemingly moving around.	0	1	2	3	4	5	6	7	8	9	10
9. It is now more difficult to correctly identify each letter.	0	1	2	3	4	5	6	7	8	9	10
10. Even when reading only a short text, it triggers or worsens my headaches.	0	1	2	3	4	5	6	7	8	9	10
Since the accident, while walking, it now more difficult for me											
11. To focus on the steps while on a stairway.	0	1	2	3	4	5	6	7	8	9	10
12. To cope with uneven places in the sidewalk or on the ground.	0	1	2	3	4	5	6	7	8	9	10
13. To avoid bumping into pedestrians, animals, a running child, or a piece of furniture.	0	1	2	3	4	5	6	7	8	9	10
14. To follow with my eyes an approaching car when getting ready to cross the street.	0	1	2	3	4	5	6	7	8	9	10
15. To keep my eyes properly focused on traffic signals such as WALK / DON'T WALK.	0	1	2	3	4	5	6	7	8	9	10

In clinical work, for obvious reasons, this Oculomotor Scale must be administered to patients in an extra large font, to make it easier to read and to minimize reading errors.

Participants

De-identified archival data of 29 post-MVA patients (12 men, 17 women) including responses to the Oculomotor Scale were available. All patients complained about signs of visual dysfunctions other than those already listed in the Rivermead Post-Concussion Symptoms Questionnaire. Age ranged from 20 to 65 years, with a mean of 43.1 years (SD=12.4). Time elapsed since their MVA ranged from 3 to 41 months, with the average of 18.3 months (SD=11.3). Twenty-three patients were the drivers, 4 were passengers, one was a pedestrian, and one was a cyclist injured in a collision with a motor vehicle.

The patients were administered the Brief Pain Inventory (Cleeland, 2009), Rivermead Post-Concussion Symptoms scale (Eyres et al., 2005), the Post-MVA Neurological Symptoms scale (Cernovsky et al., 2019), Insomnia Severity Index (Morin, 2011), and Items 10 to 12 of the Whiplash Disability Index (i.e., items to rate depression, anxiety, and anger on a scale from 0=no symptom to 10=symptom always present, see Pinfold, 2004).

The de-identified archival data were also available on 30 healthy control subjects (14 men, 16 women) who had also completed the Oculomotor Scale. Their age ranged from 19 to 74 years, with an average of 32.9 years (SD=13.7).

Results

Difference between Patients and Controls in Total Oculomotor Scores

The patients obtained significantly higher scores on the Oculomotor scale than normal controls. Total scores of the patients ranged from 23.5 to 139 points, with a mean of 86.6 (SD=32.0).

Total scores of the controls ranged from 0 to 44 points, with a mean of 5.2 (SD=10.8).

Thus, the average item score on the scale from 0 to 10 was 5.8 points for the patients and only 0.3 points for the controls. The effect size of the difference between patients and controls is very large (point biserial coefficient =.87, p<.001).

Table2. *Mean scores on each item of the Oculomotor Scale*

	Patients N=29: Mean (SD)	Controls N=30: Mean (SD)	Point biserial coefficients (all p values are p<.001, 2-tailed)
Since the accident, I have more difficulties			
1. To follow with my eyes a moving object such as a car, a flying bird, or running person.	5.7 (2.9)	.3 (.8)	.78
2. Watching a movie because it triggers or worsens my headaches.	6.7 (2.7)	.2 (.7)	.86
3. Watching a ball game and following the ball with my eyes.	6.4 (2.7)	.6 (1.7)	.80
4. Locating small food items or small food containers in the fridge.	5.1 (3.2)	.5 (1.5)	.68
5. Recognizing some simple facial expression of actors in a video.	4.4 (3.1)	.5 (1.9)	.62
6. Recognizing friends from the distance that previously would cause no such problem.	4.7 (3.1)	1.0 (2.2)	.57
Since the accident, reading causes me the following problems			
7. The words seem to "jump around" or change their location on the page.	6.6 (2.9)	.5 (1.7)	.79
8. It is now more difficult to focus on each word without it seemingly moving around.	6.1 (2.7)	.2 (.6)	.84
9. It is now more difficult to correctly identify each letter.	5.5 (2.8)	.2 (.7)	.80
10. Even when reading only a short text, it triggers or worsens my headaches.	5.9 (3.3)	.1 (.5)	.78
Since the accident, while walking, it now more difficult for me			
11. To focus on the steps while on a stairway.	6.1 (3.6)	.1 (.5)	.77
12. To cope with uneven places in the sidewalk or on the ground.	6.7 (3.0)	.3 (1.3)	.82
13. To avoid bumping into pedestrians, animals, a running child, or a piece of furniture.	5.8 (3.8)	.4 (.8)	.71
14. To follow with my eyes an approaching car when getting ready to cross the street.	6.2 (3.4)	.1 (.3)	.79
15. To keep my eyes properly focused on traffic signals such as WALK / DON'T WALK.	4.8 (3.5)	.1 (.3)	.69

The oculomotor scores were not significantly related to gender (r=.12, p>.05), but were significantly correlated with age (r=.26, p=.047). Older persons are somewhat more likely to obtain higher scores on the Oculomotor Scale. However, when re-calculating the difference between patients and controls in their oculomotor scores via partial correlation coefficient that removes the impact of age on the scores, the difference between patients and controls still remained very large and significant (r=.86, p<.001).

In the group of patients, the length of time elapsed since their accident was not significantly correlated with their oculomotor scores (r=-.06, p=.376, 1-tailed): all patients in this particular sample still experienced active post-MVA symptoms.

Responses to Individual Items of the Oculomotor Scale by Patients and Controls

The mean scores of patients and controls are summarized in Table 2. The last column of the table indicates the size of the effect, expressed as point biserial coefficients (a variety of Pearson r for correlations of variables one of which is continuous and the other dichotomous.

The data in Table 2 indicate that all 15 items of the Oculomotor Scale significantly contribute to differentiating patients from controls. In fact, the Cronbach Alpha coefficient of internal consistency calculated on this 15 item scale is very high (Cronbach's Alpha = .98).

The Item-Total correlations (item correlation to total score when the particular item is removed from the scale) were all satisfactorily high, ranging from .69 to .93.

Correlations of Oculomotor Scores to Rivermead Scale

The total oculomotor scores correlated significantly and at a high level with the total score on the Rivermead measure (Eyres et al., 2005) of the post-concussion syndrome (r=.70, p<.001). The first 3 Rivermead items (headaches, dizziness, nausea) are often considered as the early post-concussive symptoms. Their correlation to oculomotor scores was also significant (r=.53, p=.004, 2-tailed). The last 13 items of the Rivermead are considered to represent symptoms developing at a later stage of the post-concussion syndrome (see last 13 items listed in Table 3). Their correlation to oculomotor scores was also significant (r=.71, p<.001).

Correlations of individual items of Rivermead to total oculomotor scores are listed in Table 3. The correlational results were based on only 28 of the 29 patients. All correlations in Table 3 are significant at <.05 (2-tailed), except for those of the oculomotor score to "blurred vision" and "double vision." The reasons for these 2 low and nonsignificant correlations are unclear to us at this time.

Table3. *Correlations of post-concussive symptoms to oculomotor scores (N=28)*

Rivermead items:	Pearson rs:	p value (2-tailed):
1. Headaches	.43	.023
2. Feelings of Dizziness	.45	.016
3. Nausea and/or Vomiting	.49	.008
4. Noise Sensitivity, easily upset by loud noise	.66	<.001
5. Sleep Disturbance	.55	.002
6. Fatigue, tiring more easily	.52	.005
7. Being Irritable, easily angered	.56	.002
8. Feeling Depressed or Tearful	.38	.047
9. Feeling Frustrated or Impatient	.64	<.001
10. Forgetfulness, poor memory	.44	.018
11. Poor Concentration	.57	.002
12. Taking Longer to Think	.43	.023
13. Blurred Vision	.23	.238, not significant
14. Light Sensitivity, easily upset by bright light	.44	.019
15. Double Vision	.24	.212, not significant
16. Restlessness	.64	<.001

Correlations of Post-MVA Neurological Symptoms (PMNS) Scale to Oculomotor Scores

The PMNS scale (Cernovsky et al., 2019) correlated significantly with total oculomotor scores (r=.65, p<.001). The correlational results involving the PMNS scale and its individual items were based only on 28 of the 29 patients.

Correlations of the individual items of the PMNS scale to the total oculomotor scores are listed in Table 4.

Table4. *Correlations of PMNS to oculomotor scores (N=28)*

Items of the Post-MVA Neurological Symptoms scale:	Pearson rs:	p value (2-tailed):
Impaired balance	.04	.840, not significant
Excessive hand tremor	.43	.023
Sudden loss of control over leg muscles	.46	.014
Sudden loss of control over hand or arm	.55	.002
Tingling in the arm, or hand, or leg	.18	.361, not significant
Numbness in the arm, or hand, or leg	.55	.002
Reduced feeling in the arm, or hand, or leg	.46	.015
Some loss of bladder control	.46	.013
Some loss of bowel control	.32	.101, not significant
Stutter	.59	.001
Word finding difficulty	.57	.002
Difficulty articulating words	.61	.001
Noise inside of the ears (tinnitus)	.53	.004

Correlations of Oculomotor Symptoms to Ratings of Pain, Insomnia, Depression, Anger, and Anxiety

The correlations are listed in Table 5. The patients' self-ratings of pain are those on Items 3 to 5 of the Brief Pain Inventory (Cleland, 2009). Those of depression, anger/irritability, and anxiety are from Items 10 to 12 of the Whiplash Disability Index (Pinfold, 2004). The insomnia scores listed in Table 5 are total scores on Insomnia Severity Index (Morin et al., 2011).

Table5. *Correlations of oculomotor symptoms to ratings of pain, insomnia, depression, anger, and anxiety*

Symptoms:	N	Pearson rs:	p value (2-tailed):
Worst pain (Item 3 of the Brief Pain Inventory)	27	.43	.024
Least pain (Item 4 of the Brief Pain Inventory)	27	.41	.033
Average pain (Item 5 of the Brief Pain Inventory)	27	.50	.007
Insomnia Severity Index	26	.61	.001
Depression (Item 10 of the Whiplash Disability Index)	26	.61	.001
Anger / irritability (Item 11 of the Whiplash Disability Index)	25	.69	<.001
Anxiety (Item 12 of the Whiplash Disability Index)	26	.45	.020

Discussion

Traumatic Brain Injury resulting from MVAs can result in significant visual dysfunction and disability. Patients suffering from such symptoms merit an oculomotor assessment that is user friendly and efficient. The Oculomotor Scale that we propose has very satisfactory psychometric properties in terms of internal consistency (Cronbach's Alpha = .98). All items contribute significantly to its capacity to differentiate symptomatic patients from normal controls.

Its total score also robustly differentiates patients who complain of oculomotor symptoms from normal controls (point biserial coefficient =.87, p<.001). This correlation coefficient confirms the criterion validity of our Oculomotor Scale.

Convergent validity of the Oculomotor Scale is satisfactorily supported by its correlations to related important constructs such as the post-concussion syndrome (r=.70, p<.001) and to the PMNS measure

of post-accident neuropsychological symptoms (r=.65, p<.001).

The scale has not been designed as an independent instrument for diagnosis of oculomotor dysfunction (OMD): it is only intended to serve as a brief screening scale to help family physicians or medical psychologists facilitate referral for thorough professional assessments by specialized rehabilitative neuro-ophthalmologists. This scale with the patient's responses can be provided to the specialist as a component of the referral documentation, conveying a brief overview of the patient's self-ratings on each of the 15 items.

The scale is available in German, Spanish, Russian, Czech, and Arabic translations.

It appears from the correlational patterns determined in our study that oculomotor symptoms may also contribute to an increase in the subjective feelings of depression and anxiety. Similarly, the correlational results suggest that patients who report more intense pain (i.e., presumably those more severely injured in their MVAs) perhaps also sustained more intense CNS injuries with disabling oculomotor symptoms. This forms the overall context for the concussive trauma and syndrome.

It is not clear why oculomotor scores did not correlate significantly with the specific symptom items of "blurred vision" and "double vision" of the Rivermead scale (see Table 3). Some patients, especially the elderly, may experience severe blurred vision or even double vision as a side-effect of common anti-inflammatory medications such as ibuprofen: This effect could act as a confounding variable in similar studies. Further research is necessary to investigate this and other potential confounding variables, as well as the likely impact of insomnia and fatigue on oculomotor symptoms.

Studies of correlations of various clinical neuro-ophthalmological measures to the Oculomotor Scale are also much needed.

Conclusions

The victims of MVAs often report quite disabling and worrisome visual symptoms. We are hopeful that the Oculomotor Scale we have developed can be an important tool in the management of such patients. It has demonstrated very satisfactory criterion validity and convergent validity. The availability of this screening scale and its usage would potentially increase the number of referrals of patients with post-accident oculomotor dysfunction for specialized assessment and therapies by rehabilitative neuro-ophthalmologists. This would greatly benefit them and enhance their quality of life.

References

[1] Cernovsky ZZ, Istasy PVF, Hernández-Aguilar ME, Mateos-Moreno A, Bureau Y, and Chiu S. Quantifying Post-Accident Neurological Symptoms Other than Concussion. *Archives of Psychiatry and Behavioral Sciences*. 2019; 2(1): 50-54.

[2] Cleeland CS. *The Brief Pain Inventory - User Guide*. Houston, TX: The University of Texas - M. D. Anderson Cancer Center, 2009.

[3] Einarsson E-J, Patel M, Petersen H, Wiebe T, Magnusson M, Moëll C, et al. Oculomotor Deficits after Chemotherapy in Childhood. PLoS ONE. 2016; 11(1): e0147703. doi:10.1371/journal.pone.0147703

[4] Eyres S, Carey A, Gilworth G, Neumann V, Tennant A. Construct validity and reliability of the Rivermead Post-Concussion Symptoms Questionnaire. *Clinical Rehabilitation*. 2005; 19: 878-87.

[5] Morin CM, Belleville G, Bélanger L, and Ivers H. The insomnia severity index: psychometric indicators to detect insomnia cases and evaluate treatment response. *Sleep*. 2011; 34:601-608.

[6] Pinfold M, Niere KR, O'Leary EF, Hoving JL, Green S and Buchbinder R. Validity and internal consistency of a Whiplash-Specific disability measure. *Spine*. 2004; 29(3): 263-268.

[7] Rockswold SB, Burton PC, Chang A, McNally N, Grant A, Rockswold GL, Low WC, Eberly LE, Yacoub E, and Lenglet C. Functional Magnetic Resonance Imaging and Oculomotor Dysfunction in Mild Traumatic Brain Injury. *Journal of Neurotrauma*. 2019; 36: 1099–1105. DOI: 10.1089/neu.2018.5796

[8] Sinnott AM, Elbin RJ, Collins MW, Reeves VL, Holland CL, Kontos AP. Persistent vestibular-ocular impairment following concussion in adolescents. *Journal of Science and Medicine in Sport.* 2019; 22: 1292–1297.

[9] Strupp M, Kremmyda O, Adamczyk C, Böttcher N, C. Muth C, Yip CW, Bremova T. Central ocular motor disorders, including gaze palsy and nystagmus. *Journal of Neurology*. 2014;261 (Suppl 2):S542–S558. DOI 10.1007/s00415-014-7385-9

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