Article • Neuro-Optometric Rehabilitation for Post COVID-19 Syndrome

Jamie C. Ho, OD • Nashville, Tennessee

Jamie C. Ho, OD
Nashville, Tennessee

President, Ho Vision Group

BSc, University of Waterloo, Ontario, Canada

OD, Illinois College of Optometry, Chicago, IL

Community Health Residency, New England College of Optometry, Boston, MA

ABSTRACT

Background: COVID-19 is a respiratory disease that causes systemic thrombosis and inflammation, which can result in both neurologic and ophthalmological sequelae. There are reports of both physical and functional manifestations of COVID-19 in the eye and the visual system. This case discusses neuro-optometric rehabilitation efforts for a patient who suffered functional visual problems as a result of acquired brain injury following a severe COVID-19 infection.

Case Summary: A 54-year-old Caucasian male presented to clinic with complaints of visual blur and monocular diplopia following his intubation and ventilation via extracorporeal membrane oxygenation intervention after contracting COVID. Neuro-optometric rehabilitation intervention included office-based therapy, home activities, syntonics, nutrition supplementation, and referrals to other rehabilitation team members. The patient continues to have residual functional visual deficits following his recovery from COVID-19, but he was able to return to driving and working within a few months of rehabilitation.

Conclusion: Following COVID-19 infections, patients may experience subtle neurological and functional visual deficits despite a normal ocular health assessment. It is critical to have these deficits properly evaluated in a timely manner and treated, when appropriate, to support a return to acceptable quality of life. This case demonstrates how neuro-rehabilitation optometrists can optimize patient outcomes despite residual functional visual deficits following a severe acquired brain injury from COVID-19.

Keywords: acquired brain injury, neuro-optometric rehabilitation, optometric vision therapy, post COVID-19 neurologic syndrome, syntonics

Introduction

December 2019 marked the emergence of a highly pathogenic coronavirus (COVID-19) that quickly progressed into a pandemic. COVID-19 is a respiratory disease that targets angiotensin-converting enzyme 2 (ACE-2) receptors that are located throughout the body, including neural tissues. Viral downregulation of ACE-2 receptors leads to endothelial dysfunction and prolonged hyperinflammation. These conditions can result in damage to the blood-brain barrier. As a result, innate immune cells are able to enter into the brain, furthering pro-inflammatory cytokine cascade activation that also promotes coagulable states. COVID-19 appears to be able to facilitate hypercoagulable states through mediating pathways of both thrombosis and inflammation.[1]

Those with low-grade chronic inflammatory disease, such as hypertension, previous stroke, metabolic syndromes, diabetes, and obesity, have a higher probability of greater blood-brain disruption and hyperinflammation. Longer-term neurological manifestations are expected in these individuals.[2]

Persistent post-COVID syndrome, or long COVID, is increasingly recognized as a distinct entity now dubbed as post COVID-19 neurological syndrome. Symptoms from hospitalized patients with severe disease are listed in Table 1, including neurologic sequelae of neuropsychiatric disorders (e.g., delirium), ischemic stroke, and encephalitis.[3] Another study by Northwestern examined the most

Table 1. Post-COVID-19 Neurological Syndrome (PCNS)

Conditions associated with PCNS
• Dizziness • Headache • Fatigue • Loss of taste and smell • Neuropsychiatric disorders • Ischemic stroke • Encephalitis

frequent neurological symptoms in non-hospitalized long haulers, including brain fog (81%), headache (68%), dizziness (47%), and blurry vision (30%).[4] Ophthalmologic findings in severe COVID-19 cases include retinopathy (hemorrhages, cotton wool spots, dilated veins, or tortuous vessels), optic neuritis, and extramacular nodules despite otherwise unremarkable retinal findings.[5]

Visual symptoms commonly reported after acquired brain injury include pursuit and saccadic dysfunction, vergence dysfunction, accommodative dysfunction, reduced stereopsis, deficits in visual information processing, and visual field deficits.[6] Optometric vision rehabilitation therapy has been shown to improve both visual symptoms and deficits resulting from traumatic brain injury.[7,8] Such rehabilitation techniques can be used to manage and treat functional visual deficits resulting from acquired brain injury secondary to neurologic sequelae of COVID-19.

Syntonics, or the use of selective wavelengths of color, has been used to reduce visual symptoms in patients with brain injuries.[9] A small subset of photoreceptors discovered in the early 2000s is responsible for projecting information via the non-image-forming pathway. This pathway influences circadian rhythms, melatonin suppression, sleep-wake cycle regulation, cognition, emotional regulation, intracranial nociception, and pupillary constriction. Intracranial nociceptors, or pain sensory neurons, innervate intracranial blood vessels and the trigeminal ophthalmic (V1) pathway to the trigeminal ganglion. Research has demonstrated therapeutic applications of blue, red, and green light for improving cognitive performance, altering circadian rhythm, and improving migraine symptoms, respectively.[10,11]

Rehabilitation optometrists are equipped with the tools and knowledge to assess, manage, and treat both the physical and functional deficits resulting from post-neurologic effects following COVID-19 infection.

Case Report

A 54-year-old Caucasian male presented in-office the month after his hospital discharge following COVID-19 infection. Symptoms leading to his hospitalization included severe headache localized to the left side of his head, high fever, gastric upset, oxygen saturation reduced to 54%, and failure of antibiotics and steroids to provide relief for a suspected sinus infection. The patient spent 22 days in the ICU, where he was intubated and ventilated via extracorporeal membrane oxygenation. He remained partially sedated throughout his hospital stay despite intervention and oversaw his own medical care using a whiteboard to communicate.

The patient's most recent MRI prior to hospital discharge showed moderate interstitial edema with persistent subtle petechial hemorrhages within both parietal and occipital lobes, worse on the left side. The pituitary gland, sinuses, corpus collosum, hippocampal gyri, and temporal lobes were unremarkable. No additional white-matter lesions were identified, and no cortical signal abnormalities were noted. His referring discharge neurologist diagnosed him with posterior reversible encephalopathy syndrome. No other rehabilitation referrals were given.

Prior health history before COVID-19 infection was remarkable for hypercholesterolemia and hereditary bilateral hearing loss. Other history included possible head bumps sustained from playing football in high school and while repairing his car. His only medication was simvastatin.

Presenting chief complaints included occasional tripling of words, dry eye, light sensitivity to indoor light, and difficulty tracking moving targets. He was unable to track or catch a ball. The patient reported monocular diplopia that had been present following his intubation, but this symptom was slowly improving. He reported difficulty reading computer text and phone messages since images would appear momentarily clear, then blur or change position. He veered left while walking when tired. Non-visual symptoms included numbness from hips to knees on both sides, mild memory deficits, and occasional speech drop in the middle of a conversation. His functional goals were to return to driving and to his work as a flooring manager.

Assessment Findings

Examination findings are summarized in Table 2. Refractive error was minimal, but visual acuity was unstable. The patient found it impossible to read the near acuity chart when the chart was moving. Reading efficiency also decreased when peripheral movement was introduced using a swinging ball in the background of a printed chart. Ocular health was age-expected except for mild dry eye syndrome and trace age-related cataracts in both eyes. Visual-skills testing showed unstable visual posture, vergence and accommodative infacility, reduced stereopsis, and convergence insufficiency.

Table 2. Baseline Examination Findings

Test	Result
Visual acuity	OD: 20/40 OS: 20/60
Retinoscopy	Plano OD, OS
Subjective refraction	Plano OD, OS ADD +1.50
Best-corrected distance visual acuity	Fluctuates; 20/40 to 20/60 OD, OS
Best-corrected near visual acuity	Fluctuates; 20/40 OD, OS
Cover test (uncorrected)	Distance: 2 exophoria Near: 4 exophoria
Near point of convergence	24/30" (red lens, discomfort)
Worth 4-dot	4 dots in all fields of gaze
Vergence (prism bar)	Distance: BI x/10/1 BO x/4/-1 Near: BI x/4/-2 BO x/4/2 (patient constantly reported targets were blurry throughout vergence testing despite fusion)
Vergence facility	Unable to complete due to visual fluctuations
Ishihara testing	Normal in both eyes
Stereo dino test	150' seconds of dino, 0' Randot forms or Randot circles
Lighthouse contrast sensitivity testing	1.4 OD, OS.
Maddox rod	Patient was not able to stabilize stimulus with rod over either eye. He noted both intorsion and extorsion.
Maples oculomotor test (pursuits and saccades)	5,4,5,5 OD, OS (ability, accuracy, head movement, body movement)
MEM	+1.00 OD, OS (fluctuating reflex was noted) over +1.50 readers
Ocular health	Unremarkable except for mild nuclear sclerosis and vitreous floaters in both eyes

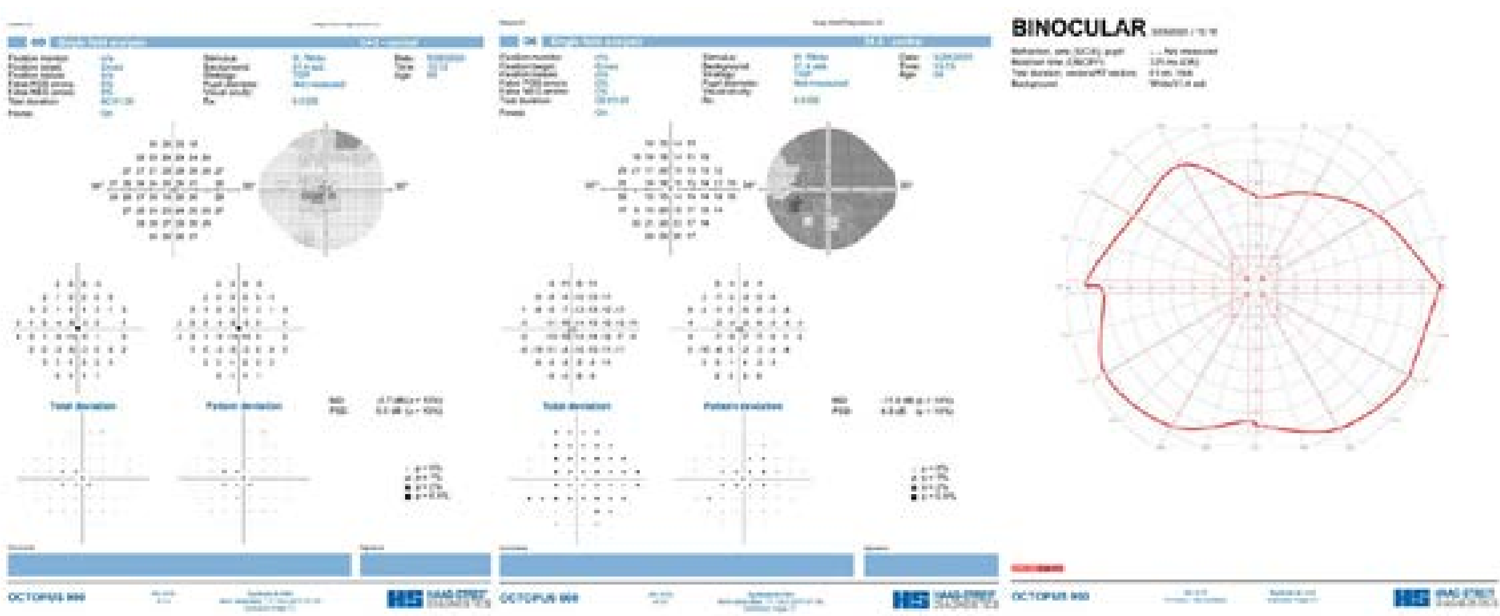


Figure 1. *Baseline threshold and kinetic visual fields; visual stamina was contributory to decreased performance of the left eye.*

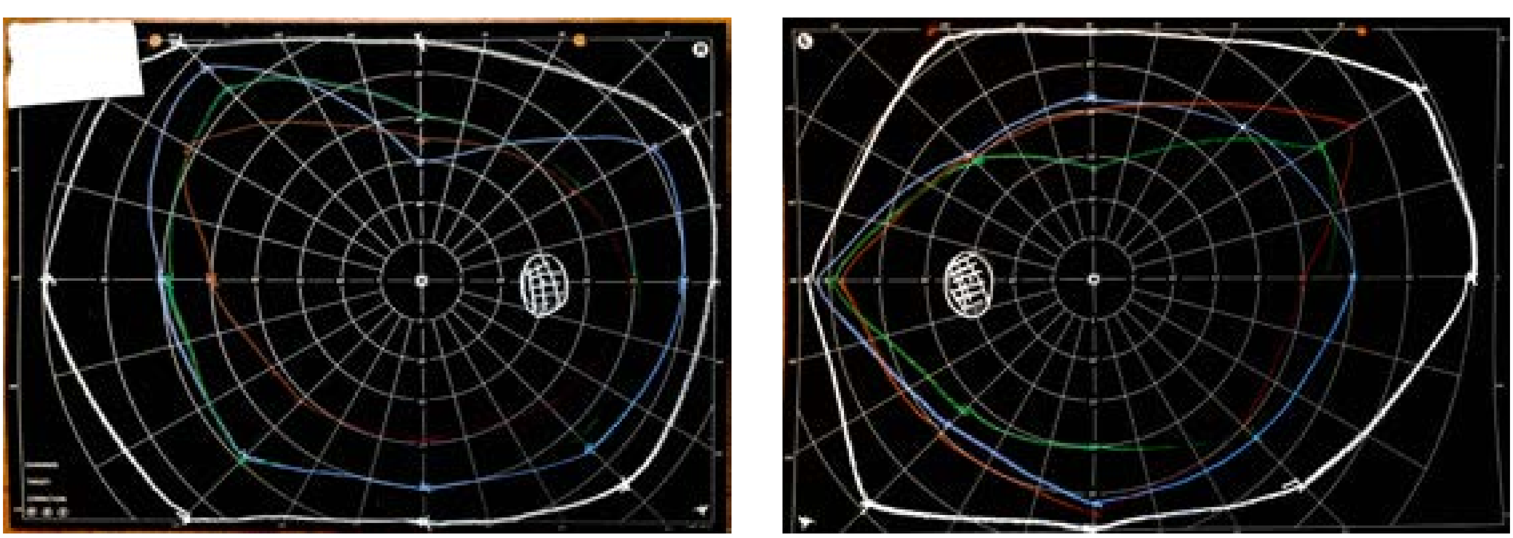


Figure 2. *Baseline color kinetic visual field; contraction and interweaving of the color kinetic fields were present.*

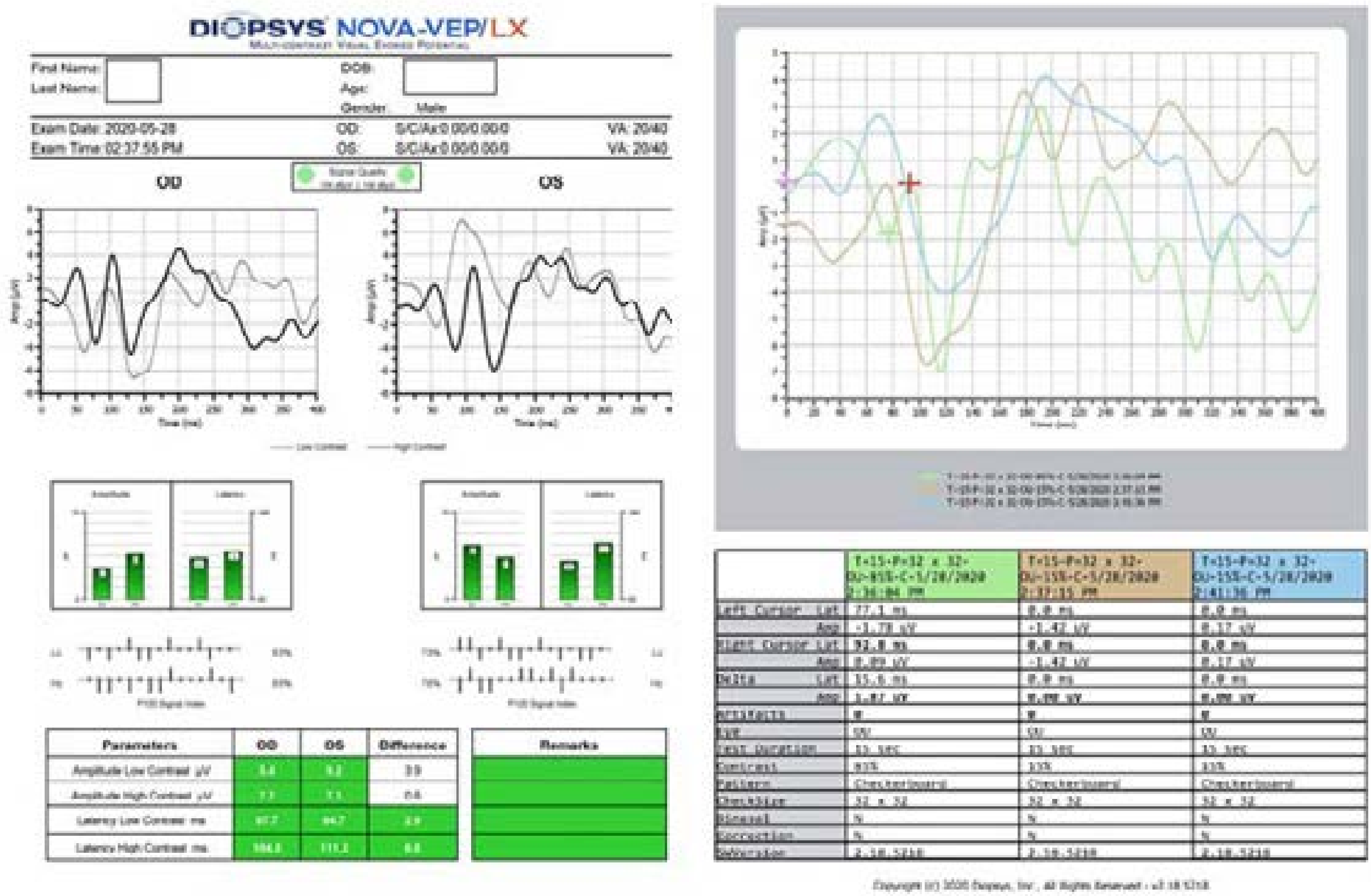


Figure 3. Baseline visual evoked potential testing using Diopsys NOVA-VEP LX and TR program showing repeatable abnormal waveform for binocular magnocellular processing

Threshold visual fields (24-2) showed mild depression in the left eye compared to the right (Figure 1). This asymmetry was performance-related due to decreasing stamina, although minimal fixation errors were noted. Kinetic visual fields were normal and full. Baseline color kinetic visual fields, shown in Figure 2, indicated mild contraction and interweaving of the color fields, although physiologic blind-spot mapping was normal in both eyes.

Visual evoked potential (VEP) testing was completed using the Diopsys NOVA-TR and LX system. A checkerboard pattern presented for 20 seconds and viewed binocularly at 2Hz temporal frequency with a central fixation target under 85% and 15% contrast was presented. The VEP showed normal monocular amplitudes and latencies for all contrast levels, but an abnormal waveform persisted with binocular low-contrast testing, as shown in Figure 3. There were brief moments of normal waveform observed during this test condition, but the patient noted discomfort with viewing this stimulus.

Diagnosis

This patient was suffering from visual dysfunctions from acquired brain injury secondary to posterior reversible encephalopathy syndrome following a severe COVID-19 infection. Visual deficits included convergence insufficiency, poor and limited vergence ranges, impaired motion processing, and visual-information processing difficulties. Ocular health was age-expected in both eyes, with the exception of mild dry eye syndrome.

Treatment Plan

Prescription blue-light-filter readers were dispensed. Prior to the infection, the patient was not using any reading eyewear. His fluctuating vision was not improved by prism, binasals, or tint in-office. Visual stamina was poor, with frequent fluctuations noted in accommodation, vergence, and visual acuity. Much of the patient's job involved digital screen time, either on the computer or cell phone, so it was important to improve visual comfort.

Omega supplement (Nordic Naturals) ProOmega 2000, approximately 3225 mg total omega (1687 EPA, 1312 DHA) daily, was supplied. Omega-3 fatty acids such as docosahexaenoic acid (DHA) have important structural and functional roles in the brain, with established clinical benefits for supporting brain development and cognitive function throughout life, in addition to improving dry eye symptoms. DHA is also used to support brain health during neurologic recovery.

Macuhealth was added three months after the initial consult. Carotenoid macular pigment supplementation, collectively lutein, zeaxanthin, and meso-zeazanthin, was used to optimize antioxidants in the retina and to enhance cognitive effects. This formulation, in a single capsule, consists of lutein (10 mg), meso-zeaxanthin (10 mg), and zeaxanthin (2 mg). The patient took one capsule orally per day.

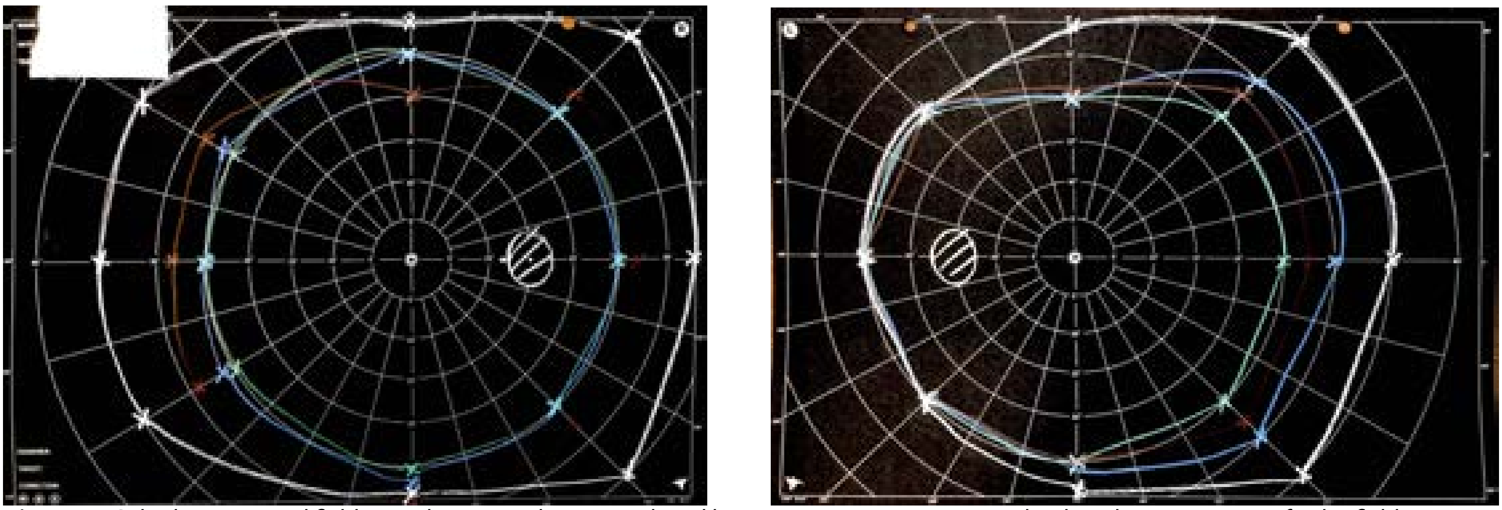
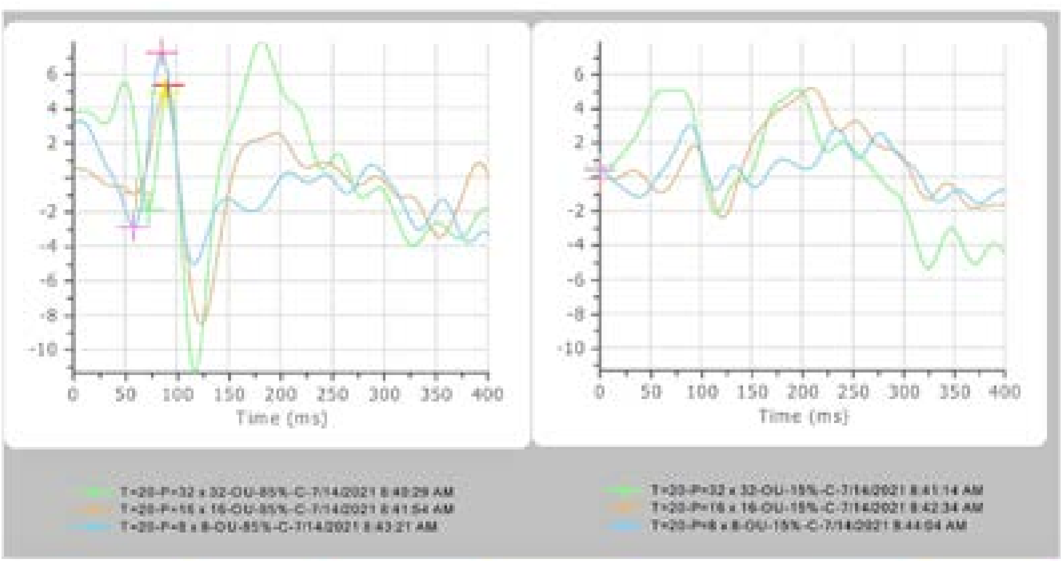


Figure 4. *Color kinetic visual field post-therapy, indicating reduced but persistent contraction and reduced interweaving of color fields.*



		T=20-P=32 x 32-OU-85%-C-7/14/2021 8:40:29 AM	T=20-P=16 x 16-OU-85%-C-7/14/2021 8:41:54 AM	T=20-P=8 x 8-OU-85%-C-7/14/2021 8:43:21 AM	T=20-P=32 x 32-OU-15%-C-7/14/2021 8:41:14 AM	T=20-P=16 x 16-OU-15%-C-7/14/2021 8:42:34 AM	T=20-P=8 x 8-OU-15%-C-7/14/2021 8:44:04 AM
Left Cursor	Lat	72.3 ms	60.5 ms	58.6 ms	0.0 ms	0.0 ms	0.0 ms
	Amp	-1.87 uV	-0.94 uV	-2.87 uV	0.55 uV	-0.16 uV	0.40 uV
Right Cursor	Lat	91.8 ms	87.9 ms	85.9 ms	0.0 ms	0.0 ms	0.0 ms
	Amp	5.37 uV	4.89 uV	7.27 uV	0.55 uV	-0.16 uV	0.40 uV
Delta	Lat	19.5 ms	27.3 ms	27.3 ms	0.0 ms	0.0 ms	0.0 ms
	Amp	7.24 uV	5.83 uV	10.14 uV	0.00 uV	0.00 uV	0.00 uV
Artifacts		1	2	2	2	2	2
Eye		OU	OU	OU	OU	OU	OU
Test Duration		20 sec	20 sec	20 sec	20 sec	20 sec	20 sec
Contrast		85%	85%	85%	15%	15%	15%
Pattern		Checkerboard	Checkerboard	Checkerboard	Checkerboard	Checkerboard	Checkerboard
Check Size		32 x 32	16 x 16	8 x 8	32 x 32	16 x 16	8 x 8

Figure 5. *Visual evoked potential testing post-therapy, with persistent magnocellular deficit in all checkboard sizes with low contrast.*

Table 3. Home and Office-Based Therapy Activities

• Hart chart saccades with addition to vestibular-ocular head movements then moving charts • In-office projected quoits and non-projected vectogram • Slotnick swirl with vestibular-ocular movement and/or bilateral gross motor activation (e.g. hand tapping) to reduce initial diplopia with initial presentation on a screen at near then progressing gradually to large distance projection • Slap tap level A-D with metronome added gradually • Marsden ball • Brock string • Infinity walking to metronome and while reading Hart chart

Table 4. Improvements in Visual Skills from Baseline Findings to Progress Evaluation following Completion of Optometric Vision Rehabilitation

Test	Baseline Evaluation Findings	Progress Evaluation Findings
Best-corrected distance visual acuity	20/40 to 20/60 OD, OS (fluctuates)	20/30 OD, OS (flicker fluctuation still noted)
Best-corrected near visual acuity	20/40 OD, OS (fluctuates)	20/20 OD, OS
Maples oculomotor test (ability, accuracy, head mvmt, body mvmt)	Pursuits: 5,4,5,5 OD, OS Saccades: 5,4,5,5 OD, OS	Pursuits: 5,5,5,5 OD, OS Saccades: 5,5,5,5 OD, OS
NPC (red lens)	24/30" (discomfort)	TTN (no discomfort)
Vergence prism bar (free space)	DBI: x/10/1 DBO: x/4/-1 NBI: x/4/-2 NBO: x/4/2	DBI: x/4/1 DBO: x/10/4 NBI: x/4/-1 NBO: x/25/18
Prism facility	Unable to complete due to visual fluctuations	10 cpm
Stereo	150' seconds of dino 0' Randot forms/circles	100" Randot circles, negative forms

Syntonics was prescribed due to contracted visual fields. Expansion of peripheral fields is expected to stabilize and improve motion processing ability. The patient used a home unit outfitted with a 40W incandescent bulb with alpha-omega (ruby) and mu-upsilon (teal) filters, 10 minutes each in a dark room without glasses daily. He completed approximately five months of syntonics with good compliance. Treatment was gradually tapered to twice per week as needed.

The goals of vision rehabilitation therapy were to stabilize pursuits, saccades, and vergence abilities and facilities and then to add head and body motion to simulate real-world tasking. Dichoptic stereoscopic techniques used peripheral awareness to improve localization. Due to a long commute, the patient was only able to come to the office once monthly. Office visits introduced new techniques and fine-tuned home-based therapy activities, with which he maintained compliance. Activities are listed in Table 3. Gross-motor work and movement of visual targets were gradually added to oculomotor and binocular activities to encourage multi-sensory integration of vision, auditory, vestibular, and proprioception. A total of six office visits were completed, with two follow-up appointments to re-assess ocular health and to ensure visual-skill stability.

Multiple referrals were also made to support the patient's return to his activities of daily living, in addition to his overall healing. Following the first appointment, a referral was made to a functional medical doctor to optimize nutrition for neurologic recovery. Another referral was made for assistive-device assessment that could provide text-to-audio to allow the patient to continue working, since reading emails and invocies was difficult for him. When visual-motion processing improved significantly, a referral was made to an occupational therapist who was a certified driving rehabilitation specialist. The patient completed and passed a behind-the-wheel assessment, which enabled him to return to work full-time.

Progress Evaluation

At the progress evaluation, completed at six months, the patient noted that words on his cell phone and computer appeared more stable, although he still noted mild visual shaking when he got tired. Words no longer appeared to double monocularly, to disappear, or to change positions. He noted that visual stability and light sensitivity improved notably after starting syntonics, then again when he started Macuhealth. He reported still not being able to read at speeds at which he had prior to the COVID-19 infection, but he attributed it to the mild cognitive impairment that persisted. He had also started on other medications and supplements from another healthcare provider, including baby Aspirin, turmeric, 5-HTP, multivitamin, B6, and magnesium.

The patient no longer veered to the left while walking when fatigued, despite having persistent neuropathy in both legs. He was driving regularly for a few months after passing his behind-the-wheel assessment with the driving rehabilitation specialist. He returned to work after three sessions of therapy and was now working 50 hours per week. He was tired when he presented to this visit.

Clinical findings that demonstrated improvement in visual skills compared to baseline are listed in Table 4. Vergence ranges were still limited but mildly improved. Mildly contracted color kinetic fields persisted in both eyes, but the degree of interweaving of the fields decreased, as shown in Figure 4. VEP, shown in Figure 5, was still abnormal for low contrast on all checkerboard sizes from 32 to 8. The patient was able to tolerate VEP testing much better compared to baseline.

It is likely that this patient could have further improved his visual skills through more optometric rehabilitation therapy sessions, but he was satisfied with his gains and was busy with work. He gradually self-weaned from all home therapy exercises as his visual stamina improved. He noted that his visual stamina worsened when he tried to cease syntonics fully, and he remained on a maintenance dose of one or two times per week.

Discussion

This case highlights the use of oculomotor and visual-skills therapy, nutrition, and syntonics in an optometric rehabilitation program. It is also important to refer to other functional providers when appropriate. Optometrists are critical team members in rehabilitation and returning patients to quality of life. In this case, visual symptoms were improved, and the patient was able to resume his job despite residual visual deficits.

Optometric vision therapy has been shown to help improve vergence, accommodation, and oculomotor dysfunctions following traumatic brain injury. Extensive repetition of oculomotor movements can improve amplitude and velocity for vergence and accommodation and can provide a decrease in patient symptoms in as little as six hours of laboratory-guided training.[12] The adult brain, despite a traumatic brain injury, has a considerable amount of neural plasticity. Dichoptic stereoscopic presentation, such as the projected Slotnick Swirl and vectographs, uses peripheral z-axis-egocentric awareness to improve target localization and to promote gross eye alignment.[13] For this patient, who did not exhibit strabismus, this technique was used to improve target localization and to provide better sensory ground for his motion sensitivity.

Gross-motor movement and auditory loading, combined with oculomotor movement later in his training, was used to mimic more real-world scenarios where vision integrates seamlessly with other sensory-motor systems. This was vital in helping the patient recover visual skills necessary for him to return to driving. Through home practice and office sessions, he was able to improve vergence ranges and facility, although vergence training and central awareness refinement were limited. Further training in these areas would probably have resulted in better end-of-day stamina, but he was satisfied with the progress. Visual skills were functional, but the patient was still mildly visually symptomatic when tired.

Visual motion sensitivity often refers to visually related symptoms, such as dizziness, imbalance, or disorientation, in response to peripheral moving stimuli. This patient, however, did not have these complaints, but his ability to read was impaired by background motion, suggesting some variant of visual motion sensitivity. This assumption of magnocellular damage from encephalitis was supported by initial VEP findings. Despite improvement in visual performance and reduction of visual symptoms by the end of optometric vision rehabilitation, VEP findings were still abnormal for binocular magnocellular processing, which appeared to correspond with his complaints of visual motion reoccurring when he was fatigued.

Visual field loss can result from pathology in the retina and/or brain. Although standard threshold perimetry and kinetic visual fields were normal, field constrictions were only discovered during color kinetic visual field testing. This finding suggests that despite residual edema in the parietal and occipital lobes, the damage was diffuse. Functional color field constrictions result from fatigue or from toxic, nutritional, emotional, or physical stress. This type of field testing is much more sensitive at detecting physiological imbalances in oxygen, edema, or metabolism when the tissue is damaged but not fully destroyed.[9] The need for this patient to continue syntonics maintenance after a failed attempt to stop this form of therapy suggests that syntonics is continuing to support his recovery from the extensive neurologic injury from COVID-19.

Optimizing diet for neurologic recovery is ideal. Omega supplements were initiated early in treatment, both to address the dry eye and to reduce the secondary neuronal damages, like oxidative stress, from the traumatic brain injury. Improvements in episodic and working memory, spatial learning, attention, and reaction time have been observed by supplementing DHA to healthy young adults whose habitual diets were low in DHA.[14] Mechanistic investigations suggest that DHA influences multiple aspects of the pathologic molecular signaling cascade that occurs after mild traumatic brain injury.[15,16]

Macular pigment antioxidant carotenoids are found naturally in high concentrations to neutralize free radical products resulting from a metabolically demanding macula. Supplementation has correlated to visual acuity improvements when treating those with age-related macular degeneration.[17] Studies have shown significant dose response for lutein and zeazanthin supplements with their ability to increase macular pigment, reduce inflammatory factors, and improve glare and photostress recovery in healthy individuals.[18] More recently, changes in macular pigment optical density along with brain-derived neurotrophic factor appear to correlate with improved speed of cognitive processing and complex processing, as well as memory enhancement.[19,20] Supplements were used to optimize both vision and brain health for neurologic recovery in this case.

Conclusion

Optometrists are critical team members in rehabilitating and improving patient outcomes in those with functional visual deficits after acquired brain injury secondary to COVID-19 infection.

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Correspondence regarding this article should be emailed to Jamie C. Ho, OD at jamie.ho@hovisiongroup.com.

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