

Physical Therapy Treatment of a Person Exposed to Directed Energy: A Case Report

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ABSTRACT Directed energy exposure is a phenomenon that has been reported in Cuba and China by both U.S. and Canadian government employees. Persons exposed to directed energy report symptoms that resemble mild traumatic brain injury (concussion). No single case has been reported in the literature. A 43-year-old male with suspected directed energy exposure developed progressively worsening headaches, dizziness, auditory/vestibular symptoms, balance problems, difficulty sleeping, and cognitive/emotional complaints while assigned by the Department of State to Guangzhou, China. His physical therapy care is outlined and discussed to provide an in-depth understanding of his care and additional ideas that might benefit future diplomats and government employees who experience dizziness, visual complaints, and balance problems after suspected directed energy exposure. Coordinated multidisciplinary care with benchmarks of function before deployment is advised by the National Academies of Sciences.

INTRODUCTION

Directed energy exposure is a phenomenon that has been reported in Cuba and China by both U.S. and Canadian government employees.^{1,2} In the National Academies of Sciences, Engineering, and Medicine 2020 report, the committee suggested that the symptoms that the Department of State employees experienced were similar to what would be expected after exposure to directed, pulsed microwave energy.³ The Frey effect has been described as producing pressure, dizziness, and sounds such as knocking or buzzing in the head after exposure to radio frequency energy in hearing and deaf persons.³

Jauchem and Cook described three categories of potential effects of audible, acoustic energy: (1) aural effects (temporary or permanent effects on hearing), (2) extra-aural effects due to activation of the sympathetic nervous system (increased heart rate and blood pressure), and (3) nonaural effects (pain, vertigo, nausea, and vomiting).⁴ The possible effects of infrasound and low-frequency acoustic energy were less clear.⁴

There is no standardized methodology for testing exposure to directed energy, so it remains unclear how directed (microwave) energy affects the human brain.^{1,5} Typical symptoms that resemble mild traumatic brain injury

(mTBI; concussion), including dizziness, imbalance, headache, visual complaints, cognitive deficits, difficulty with sleep, and anxiety, have been reported by the U.S. and Canadian employees who were exposed to directed energy.⁶ Twenty-five diplomatic personnel reported dizziness, unsteadiness, cognitive impairments, otalgia, tinnitus, and hearing loss following the suspected sonic attack in Cuba.² Although aggregate data have been published,^{1-3,6,7} no single case has been reported in the literature.^{1,2,6-9} The purpose of this manuscript is to describe the presentation and course of care for a person exposed to directed energy. An overview of the patient's major signs and symptoms following exposure to directed energy is presented in [Table I](#). We offer recommendations that might benefit future diplomats and government employees who experience dizziness, visual complaints, and balance problems after suspected directed energy exposure.

CASE REPORT

A 43-year-old male was working as a security engineering officer for the U.S. Department of State in Guangzhou, China. In November 2017, he developed lightheadedness and dizziness, with later complaints of short-term memory loss, headaches, irritability, and sleep difficulty with waking in the middle of the night and not being able to go back to sleep for up to 2 hours. He and his wife reported hearing sounds like “steel marbles dropping on glass and then rolling in a steel funnel” late at night in their apartment. It was verified that the upstairs neighbor was not responsible for the sounds. His wife had similar symptoms but was not included in the Cuba or China reported cohorts. He had no history of mTBI before the onset of his symptoms.

Six Months After Symptom Initiation

Six months later, he had developed intense headaches and dizziness. When he was medically evacuated to a state-side medical university hospital in June 2018, his chief complaints were intermittent headaches (pain rating 5 out of 6),

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TABLE I. Overview of the Patient’s Major Signs and Symptoms following Exposure to Directed Energy

Time period	Signs	Symptoms
Point of injury		<ul style="list-style-type: none"> - Lightheadedness and dizziness - Later complaints of short-term memory loss, headaches, irritability, and sleep difficulty
6 months after injury	<ul style="list-style-type: none"> - Convergence insufficiency - Abnormal dynamic visual acuity (loss of three lines to the left and eight lines to the right with an instrumented device at 85 to 120 deg/s) - Abnormal neuropsychological testing with low scores on a visual puzzle task, visual-motor fluency, cognitive flexibility, and receptive language - Mood was normal 	<ul style="list-style-type: none"> - Intense headaches and dizziness - Then, intermittent headaches, imbalance, and dizziness - Sleep difficulty, visual complaints such as difficulty looking at a computer screen and reading - Nausea with pursuits, VOR, and head shake test - Motion sensitivity with VOR cancellation
9 months		- “Light” headaches
1 year		- Headaches provoked by working at a computer
2 years	<ul style="list-style-type: none"> - Right exodeviation and a slight left hyperdeviation - Saccadic eye movements were dysmetric, right greater than left - Convergence insufficiency - Vision blurred with head movements over 130 beats per minute 	<ul style="list-style-type: none"> - Short-term memory loss, difficulty in sleeping, photophobia, and headaches - Fatigue with saccadic exercises and vergence
2.5 years		<ul style="list-style-type: none"> - Mild dizziness; dizziness with activities that increased his heart rate and computer work - Decreased balance confidence; moderate concern for falling - Complaints of visual vertigo - Headaches while sprinting - Irritability, feeling more emotional, feeling slowed down (slowed thinking), and difficulty concentrating - Feeling mentally “foggy” - Sensitivity to light and difficulty remembering - Symptoms related to convergence insufficiency - Difficulty with spatial navigation

imbalance, and dizziness. He was diagnosed with mTBI and was prescribed 400 mg magnesium and 400 mg riboflavin daily plus 25 mg of Elavil (amitriptyline HCl) three times per day. He was having difficulty with sleep, visual complaints when looking at a computer screen and reading, as well as headaches. The university hospital team suggested cognitive therapy, oculomotor therapy, vestibular physical therapy, and daily physical exercise.

He performed daily eye tracking and vergence exercises with a Brock string plus gaze stabilization exercises. He was prescribed 400 mg magnesium and 400 mg riboflavin daily plus 25 mg of Elavil (amitriptyline HCl) three times per day. His sleep improved allowing him to sleep for up to 7.5 h/night.

Initially, his Sensory Organization Test composite score was normal (Fig. 1), but he had difficulty with conditions 4, 5, and 6. No falls were reported. Convergence was 12 cm, and he reported “some nausea” with pursuits. “Fast” Vestibulo-Ocular Reflex VOR x 1 plus the posthead shake nystagmus test caused mild nausea, and VOR cancellation created mild motion sensitivity. His dynamic visual acuity was abnormal with a loss of three lines to the left and eight lines to the right with an instrumented device at 85 to 120 deg/s.

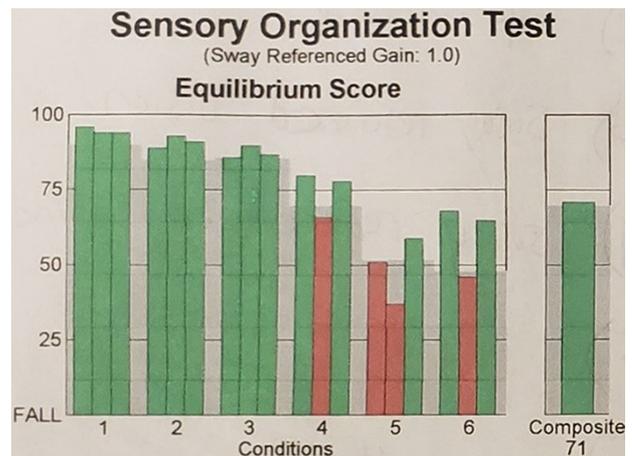


FIGURE 1. Sensory Organization Test scores for a 43-year-old man exposed to directed energy immediately after his medical evacuation.

He underwent 7.5 hours of neuropsychological testing, which included tests of his writing, reading, executive function, visual perception, intellect, mood, plus additional

standardized tests. Neuropsychological testing revealed “relative compromise” of auditory and visual memory, motor functioning, receptive language, visual reasoning, cognitive flexibility, confrontational naming, and an area of visual-motor construction. He was prescribed tinted lenses by an optometrist for computer use, overhead lighting, and for sunny days but no longer wore regular glasses after Lasik surgery. His unaided visual acuity was 20/20.

Nine Months Postonset of Symptoms

He reported that he was close to 95% of his prior level of function and had discontinued cognitive therapy 2 months prior. He remained on a low dose of amitriptyline HCl and reported that his headaches were “light” with a frequency of one to two times per week. He reported compliance with balance exercises one to two times per week plus gaze stabilization exercises and Brock string exercises to improve vergence. He was exercising on a high-density foam pad at home and denied falls. His Sensory Organization Test scores had improved (Fig. 2). He had resumed running and was attempting to cross-country ski up to 1.5 h/day. His Functional Gait Assessment score was 30/30,¹⁰ and his Balance Error Scoring System score was 9 out of 60, which are both normal scores.¹¹ MRI findings suggested small T2 bright foci in the frontal regions.

One Year Postonset of Symptoms

He continued his medication regimen for 1 year and continued to experience headaches that were provoked (incidence and intensity) with working greater than 4 hours on a computer. Subsequently, his amitriptyline HCl was increased to 50 mg three times per day.

Two Years Postonset of Symptoms

He now reported short-term memory loss, difficulty in sleeping, photophobia with bright sunlight, and headaches that

occurred in the late afternoon. He worked 50% of his day at home and 50% in the office, which improved his symptoms. Previously, he worked in the office full-time.

The physical therapist reported a right exodeviation with the cross-cover test and a slight left hyperdeviation. Utilizing EYE-SYNC’s (SyncThink Inc., Palo Alto, CA) visual tracking software, smooth pursuits were normal, but saccadic eye movements were dysmetric, right greater than left. Near-point convergence was 7.3 cm (mean of three repetitions). His dynamic visual acuity (tested with a handheld Snellen chart) was normal. The patient was able to perform VOR x 1 at 130 bpm while maintaining gaze on a clearly viewed target, but at faster speeds, his vision blurred. He was prescribed VOR x 1 exercises (with the goal of increasing his head speed by 5-10 bpm while keeping the target clear), saccadic exercises, and vergence exercises (using a Brock string one to two times per day but cautioned that the vergence exercise can cause headache). He reported fatigue with the saccadic exercises and vergence. He was provided with a list of computer apps/games that were designed to enhance his concentration plus the ability to perform saccadic and smooth pursuit eye movements.

His signs and symptoms were similar to persons who have had an mTBI (concussion). Figure 3 illustrates his symptoms that are commonly seen in persons postconcussion as they relate to concussion clinical subtypes.

Two-and-a-Half Years Postonset of Symptoms

The patient agreed to complete questionnaires to characterize his remaining symptoms and to inform clinicians. His Dizziness Handicap Inventory score was 26 (subscale scores: physical 4, emotional 14, and functional 8), indicating mild dizziness, which had not changed since 3 months postremoval from duty. On the Vestibular Activities Avoidance Instrument 9-Item,¹² he reported dizziness with activities that increased his heart rate and that computer work sometimes increased his symptoms. His Activities-specific Balance Confidence Scale score was 89%, with 100% indicating no balance concerns.¹³ His Activities-specific Balance Confidence Scale score had remained stable (between 89% and 95%) since he was initially removed from duty. His Falls Efficacy International score was 20, and scores of 20-27 suggest a moderate concern for falling with scores ranging from 16 to 64 in persons with vestibular disorders and older adults.¹⁴

On the Visual Vertigo Analogue Scale,¹⁵ he had symptoms with being a passenger in a car, being under fluorescent lights, going down an escalator, and walking over a patterned floor. Scores on the Visual Vertigo Analogue Scale range from 0 to 10 on each item, with 0 equating to “no dizziness” and 10 equating to “most dizziness.” His worst rating was being under fluorescent lights (3 out of 10). When asked additional questions about being under flickering lights, his score was 5 out of 10 and he had a rating of 2.5 out of 10 when asked about being a passenger in the back seat of a car.

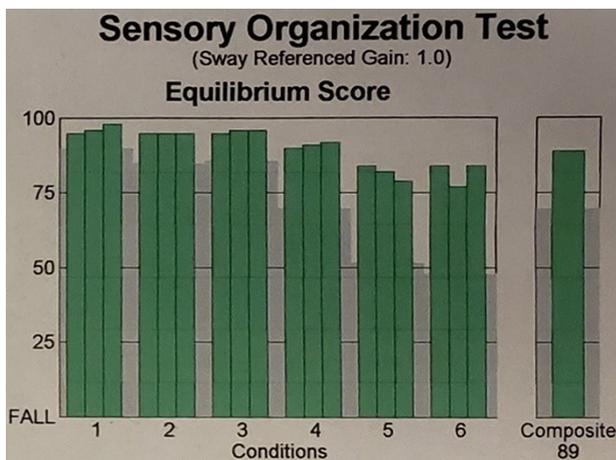


FIGURE 2. Sensory Organization Test scores 9 months after removal from the U.S. Embassy.

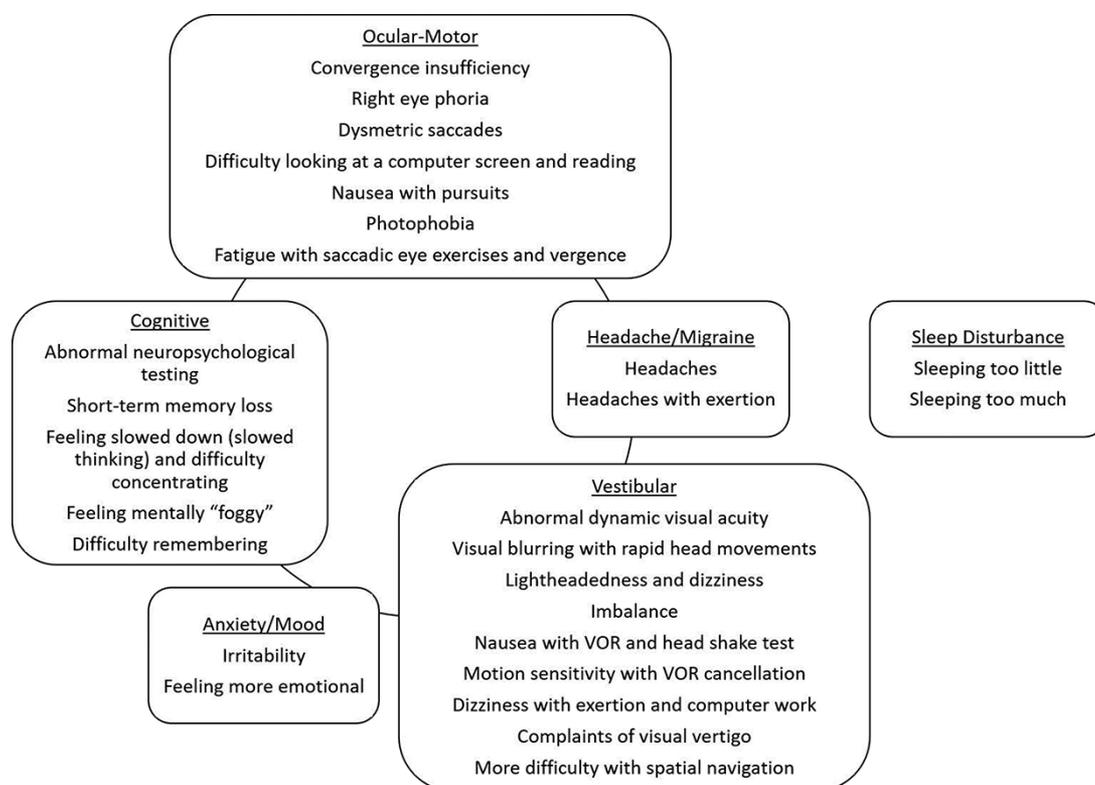


FIGURE 3. Symptoms reported by a 43-year-old male exposed to directed energy that are commonly seen in persons postconcussion as they relate to concussion clinical subtypes (ocular-motor, headache/migraine, vestibular, anxiety/mood, and cognitive) and associated conditions (sleep disturbance).

He completed the Life Space Assessment,¹⁶ which records how much people move about in their environment, the frequency of their movements, and their level of independence over the last 4 weeks. He had a perfect score on the Life Space Assessment and reported that most days he went swimming or cross-country skiing. He reported that when his heart rate increased while sprinting, he sometimes experienced dizziness or headaches.

This patient had many symptoms typically associated with persons postconcussion.¹⁷ His Post-Concussion Symptom Scale score was 38 out of 132.¹⁸ On the Post-Concussion Symptom Scale, persons rate their symptoms on a Likert scale from 0 (none) to 6 (severe). He rated the following as 5 out of 6: irritability, feeling more emotional, feeling slowed down, and difficulty concentrating. He rated feeling mentally “foggy” as 4 (moderate) and rated both sensitivity to light and difficulty remembering as 3.

On the Clinical Profile Screening tool that was developed for persons postconcussion,¹⁷ his highest (worst) score was in the cognitive fatigue profile (mean, 1.3). Scores on the profiles range from 0 to 3. He scored 0.4 for both the ocular and vestibular profiles, suggesting that cognitive fatigue affected his function in daily life as did the oculomotor and vestibular systems.

As many of his symptoms related to cognitive fatigue while working at a computer and being under fluorescent lights, he

was asked to complete the Revised Convergence Insufficiency Symptom Survey.¹⁹ Although originally designed for children, it has been validated in an adult cohort and demonstrated good reliability and validity.²⁰ He reported “fairly often” for the following items: do your eyes feel tired when reading or doing close work? do you feel sleepy when reading or doing close work? do you lose concentration when reading or doing close work? and do you have trouble remembering what you have read? He reported “sometimes” for the following items: do your eyes feel uncomfortable when reading and doing close work? do you have headaches when reading or doing close work? do you feel like you read slowly? do you feel a “pulling” around your eyes when reading or doing close work? do you lose your place while reading or doing close work? and do you have to reread the same line of words when reading?

Because he reported that his sense of direction was not as good as before May 2018, he completed the Santa Barbara Sense-of-Direction scale.²¹ Although he trained as an engineer, he now stated that he had more difficulty with his “sense of direction,” getting lost in a new city, reading maps, understanding directions, remembering routes as a passenger, remembering a new route after traveling it once, and having a good “mental map” of his environment.

The Spatial Apperception Test is designed to gauge the ability to visualize objects in three dimensions. On the Spatial

Apperception Test (a subset of the Aviation Selection Test Battery that is used by the U.S. Marine Corps, navy, and Coast Guard to select pilots),²² his score was in the 7th percentile. Twenty-four years prior, he had taken the same test under the same conditions and scored in the 67th percentile.

The patient completed the Brief Illness Perception Questionnaire, which is composed of nine questions that relate to how well the person understands their condition, his sense of control, how likely he feels that he will get better, and his emotional response to his injury.²³ His Brief Illness Perception Questionnaire responses were similar to responses collected in 15 persons with persistent postural-perceptual dizziness (PPPD) that was reported in a recently published case-control pilot study.²⁴ Five of the nine items he scored were within one point of the mean of the 15 subjects with PPPD. The PPPD cohort had a mean age of 62 years, with a mean duration of symptoms of 79.5 months. The PPPD subjects were older and more chronic than our patient. He endorsed statements that suggested that his illness severely affected his life and that his symptoms would persist for a long time. His symptoms continue to affect him and his emotions (both were rated as 7 out of 10 with 10 meaning that his problem severely affects his life).

Headaches continue to cause distress. His Migraine Disability Assessment Test score was 13, with 11-20 suggesting moderate disability.²⁵ He reported 12 days within the last 3 months where he experienced headache with a mean headache rating of 6 out of 10.

He completed the Neurobehavioral Symptom Inventory, which is used by the Department of Veterans Affairs to record postconcussive symptoms.²⁶ His scores were worst on irritability, slowed thinking, and poor concentration, all with scores suggesting that within the last 2 weeks the symptoms were present and disrupted activities. He endorsed symptoms above "0" on 12 of the 22 questions of the Neurobehavioral Symptom Inventory.

DISCUSSION

A vestibular physical therapy evaluation for individuals exposed to direct energy has been described by Hoppes et al., but not all facets of that exam were included in this case.²⁷ The care provided to this patient was disjointed and spanned over a 2.5-year period. During this time, he was seen in physical therapy clinics eight times and care was provided by two different physical therapists. There was little information on the patient's treatment or response to treatment in his medical records from other facilities, which is a limitation of this case report. The lack of a systematic approach to his examination, treatment, and follow-up highlights the need for improved care of this type of injury across the DoD and Department of State. It is unclear if his outcomes would be different if he had been treated more intensely earlier; however, it is known that people with vestibular disorders who are treated within weeks of diagnosis have better outcomes.^{28,29}

Although he was told to perform exercises at home, his vestibular rehabilitation care was episodic with months between return visits, which is atypical of persons receiving vestibular physical therapy as most people are seen on a weekly basis or more frequently.³⁰ There are no specific recommendations for treatment frequency in the new concussion clinical practice guideline developed for physical therapists.³¹ However, the VA/DoD Clinical Practice Guideline for the Management of Concussion-Mild Traumatic Brain Injury suggests that clinicians offer a short-term trial of specific vestibular, visual, and proprioceptive therapeutic exercise for individuals with mTBI who present with impairments due to dizziness, disequilibrium, and spatial disorientation.³² Similarly, the Berlin consensus statement on concussion suggests that a targeted vestibular rehabilitation program has value for persons with persistent vestibular symptoms.³³

Exposure to "directed, pulsed radio frequency energy" has resulted in clinical signs and symptoms that are unique compared to other neurologic or medical conditions.³ Acute cognitive and auditory/vestibular symptoms were evident without any known injury mechanism.³ Conversely, blast-induced traumatic brain injury can be due to the primary, secondary, tertiary, or quaternary effects caused by a known mechanism of injury (i.e., improvised explosive device and rocket propelled grenade). Patients with a history of mTBI associated with an acceleration/deceleration mechanism of injury may have anosmia, while patients with a history of blast-induced mTBI may have hearing loss.³² A sample of 25 diplomatic personnel have reported hearing loss after exposure to directed injury,² similar to blast-induced traumatic brain injury. To our knowledge, anosmia has not been reported by individuals exposed to directed energy.

Common findings in this case that are seen in persons post-concussion as they relate to concussion clinical subtypes are included in [Figure 3](#). The 2016 DoD/VA Clinical Practice Guideline for the Management of Concussion-Mild Traumatic Brain Injury strongly recommends against adjusting treatment strategy based on mechanism of injury.³² A recent recommendation suggests implementation of multidisciplinary, coordinated care for future U.S. Department of State cases with baseline data collection and systematic data collection upon their return to the USA for care, if needed, postexposure.³⁴ Early interdisciplinary rehabilitation was recommended by the National Academies of Sciences committee, but it is not clear what interventions are optimal. The National Academies of Sciences report suggested that persons with chronic conditions improved after referral for either cognitive or vestibular physical therapy based on the larger directed energy studies.^{2,6,34}

The patient reported the sound of steel balls dropping on a class surface was reported at the time of symptom onset. Lederman et al. reported that the sounds experienced differed markedly between diplomats.³⁵ Diplomats (30 out of 40 subjects) have reported either high- or low-pitched sounds or pressure when questioned about their initial exposure.⁷

After returning to the USA, the patient's objective dynamic visual acuity testing was abnormal; he lost eight lines when moving his head to the right and three lines when moving his head to the left. Two years later, when tested in another physical therapy clinic with objective eye movement testing, he had dysmetric saccades that were worse to the right than to the left. The consistency in the eye movement responses to the right was interesting and was noted 2 years later. Oculomotor performance may be an important biomarker for injury in this population.

Verma et al.⁷ reported that persons exposed to directed energy had changes in regional gray and white matter volume, whole white matter volume, changes in the cerebellum, and changes in visuospatial and auditory subnetworks compared to healthy control subjects. This individual had T2 bright foci noted in the frontal regions. T2 bright foci are one of the most frequent findings in cerebral MRI,³⁶ and it is not known if these are an incidental finding or evidence of directed energy exposure.

Shahin et al.^{37,38} have reported that exposure to 2.45-GHz microwave radiation in mice negatively affected spatial memory and learning. Difficulties with visuospatial concepts and spatial memory/learning correspond with our patient's symptoms, with his perceived changes in spatial navigation evident with the Santa Barbara Sense-of-Direction Scale plus his scores on the Spatial Apperception Test. It is unknown what effect age has on the Spatial Apperception tasks, but the change from the 67th percentile to the 7th percentile appears to be dramatic.

Differential diagnoses were considered for this case, and although our patient reported some responses on questionnaires that were similar to persons living with PPPD (such as beliefs that his illness was severely impacting his life and that his symptoms would persist for a long time), his responses were not totally consistent with the responses of people with PPPD as reported by Trinidad et al.²⁴ His symptoms did not last for prolonged periods of time and were often related to fatigue, suggesting that he does not meet all of the Barany Society's criteria for PPPD.³⁹ As PPPD is a functional vestibular disorder, not psychiatric diagnoses, symptoms may be triggered by neurologic, vestibular, psychologic, or other medical conditions.³

Others have recently suggested that rather than brain injury, vestibular migraine might be the cause of the diplomats' symptoms.⁸ Our patient has experienced headaches plus many of the symptoms seen in persons with vestibular migraine. Vestibular rehabilitation has been shown to reduce symptoms in persons living with vestibular migraine.⁴⁰

Regardless of his diagnosis, he continues to be functionally impaired. Future diplomats should be evaluated early and followed up in a systematic manner to prevent long-term sequelae.³⁴

This case was based on data recorded in a clinical manner over 2.5 years, which is a limitation of the case report. There were gaps in his examination findings, limited descriptions of

his prescribed interventions, and changes in his presentation over time. Changes in his presentation over time may have been because of inconsistencies in what data were collected over time, as he received care at several different institutions and from many different healthcare providers. Additionally, his clinical presentation may have truly changed or have been affected by medication, sleep, or other factors. Despite these limitations, this case report provides details of one person's post-directed energy experience, which has not previously been described in the literature.

CONCLUSIONS

To our knowledge, this is the first case report of a person exposed to directed energy. Previous data from past studies presented aggregated data.^{6,8,9} Over 2 years after exposure to directed energy in China, our patient remains symptomatic but is much improved compared to when he was medically evacuated to the USA. He continues to report fatigue plus ocular and vestibular issues. The episodic nature of his vestibular rehabilitation care may have resulted in suboptimal outcomes. In the future, persons exposed to directed energy should be evaluated early and followed systematically over time to aid in their rehabilitation and return to duty.

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CONFLICT OF INTEREST STATEMENT

None declared.

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