Neurological Vision Rehabilitation: Description and Case Study

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Abstract: The wars in Afghanistan and Iraq have been notable for the high rates of traumatic brain injury (TBI) that have been incurred by the troops. Visual impairments often occur following TBI and present new challenges for rehabilitation. We describe a neurological vision rehabilitation therapy that addresses the unique needs of patients with vision loss that is due to TBI.

The wars in Afghanistan and Iraq have been notable for the high rates of traumatic brain injury (TBI) that have been incurred by the troops (Hayward, 2008). The need to develop effective rehabilitation strategies has been highlighted by service members who are returning with visual deficits secondary to brain injury. In 2003, the Western Blind Rehabilitation Center (WBRC), a center-based program at the Palo Alto Veteran's Affairs (VA) Medical Center, began to admit service members with neurological visual impairment, many of whom had "polytrauma" injuries. *Polytrauma injuries* are defined as multiple injuries, occurring simultaneously, in which one or a combination of injuries are life threatening. The injuries can include traumatic amputations, burns, penetrating injuries to one or more areas of the body, infections, paralysis, internal injuries resulting from a blast wave, and damage to the sensory organs (Ritenour & Baskin, 2008). TBI often accompanies polytrauma injuries and can range from mild to severe (Belanger, Kretzmer, Yoash-Gantz, Pickett, & Tupler, 2009; Taber, Warden, & Hurley, 2008). In these patients, TBI is often associated with a blast-related event, such as an improvised explosive device or a rocket-propelled grenade. However, brain injury can also result from gunshot wounds, motor vehicle accidents, anoxia, stroke, and other causes. The visual symptoms of a blast-related TBI are often similar to the symptoms presented with other mechanisms of injury, such as stroke, motor vehicle accidents, falls, and assaults (Belanger et al., 2009; Brahm et al., 2009).

Patients with TBI at the Palo Alto VA often present with visual impairments and dysfunctions resulting from an injury to the brain, rather than a direct injury to the eye or orbit (Brahm et al., 2009; Cockerham et al., 2009; Goodrich, Kirby, Cockerham, Ingalla, & Lew 2007; Lew et al., 2007; Lew et al., 2009; Stelmack, Frith, Van Koevering, Rinne, & Stelmack, 2009). Injury to the brain will produce

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visual symptoms, depending on the area or areas of the brain in which damage occurred. Brain injury may result in reduced visual acuity, loss of a visual field (such as the nasal or temporal field and quandranopia and hemianopia either in the superior or inferior field), and binocular vision disorders. Accommodative dysfunctions, convergence insufficiency, and ocular motor deficits are examples of binocular vision disorders (Brahm et al., 2009; Goodrich et al., 2007; Lew et al., 2007). Functional implications of binocular vision disorders include reading difficulties (such as losing one's place, comprehension, and endurance), diplopia, eye fatigue, gait and postural imbalance, attention, and concentration.

The treatment of patients with neurological visual impairment secondary to brain injury can be challenging. For example, patients may have physical injuries and other limitations, including amputation, weakness, paralysis, or apraxia (the inability to carry out purposeful movements). Also challenging are the cognitive, language, and psychosocial issues that often accompany severe injury. The cognitive skills that may be affected include memory, judgment, mathematical skills, attention, and decision making. Language skills may also be affected in patients who are diagnosed with aphasia, the inability to produce or comprehend language. In many cases, the psychosocial issues that these patients face make the rehabilitation process more challenging. These issues may include posttraumatic stress disorder (PTSD), depression, anxiety, and sleep disorders (Vanderploeg, Belanger, & Curtiss, 2009). In addition, psychosocial issues affect personal and social relationships as well as educational and vocational pursuits. Such factors may contribute to the development of poor coping strategies, including substance abuse and social withdrawal (Yu, Wagner, Chen, & Barnett, 2003).

Because of the complex nature of TBI-related injuries, patients require a comprehensive treatment team of professionals. For example, neuropsychologists address cognitive, emotional, and psychological symptoms, while physical therapists address problems with balance, muscle weakness, gait, and other issues. Other members of the rehabilitation team may include nurses, audiologists, speech and language therapists, occupational therapists, and other clinicians. To provide a more comprehensive treatment approach, the model described in this article includes optometrists, vision rehabilitation specialists, and orientation and mobility (O&M) specialists as integral members of the rehabilitation team. Consultation with optometrists is ongoing, since these consultations provide essential information on the functional vision of the patients throughout the spectrum of their treatment program.

Development of the Comprehensive Neurological Vision Rehabilitation (CNVR) Program

The WBRC is an in-patient facility that provides rehabilitation in five primary treatment areas: visual skills, O&M, living skills, computer access training, and manual skills. It is supported by optometry, psychology, social work, recreation therapy, and rehabilitation nursing. Prior to the conflicts in Afghanistan and Iraq, the "typical" patient was male in his early 70s with a vision loss that was due to an age-related eye disease. By contrast the "typical" patient from the current wars is aged 19–39 and incurred a TBI resulting in neurological visual impairment (Brahm et al., 2009; Goodrich et al., 2007). Initially, rehabilitation efforts attempted to integrate patients with neurological visual impairment into the existing treatment model, which had evolved primarily to address the needs of patients with age-related eye diseases. This approach proved to be ineffective, and the new CNVR treatment model was developed.

Developing the CNVR program required substantial time and effort (Koons, Johnson, Kingston, & Goodrich, in press). This effort used local resources, including literature reviews and additional staff education and training. The training built on research conducted in the Polytrauma Rehabilitation Center (PRC), which was designed to characterize and describe the functional vision loss in members of the combat service with polytrauma injuries (Goodrich et al., 2007).

Although the initial impetus came from patients with combat-related injuries, the reputation of the program within the Palo Alto Medical Center and elsewhere generated a flow of patients with brain injury related to stroke, motor vehicle accidents, falls, and other causes. As a result, the WBRC has served an increasing number of patients with neurological visual impairment that is due to a variety of causes. In the five years before the inception of the CNVR, 3%–5% of WBRC admissions were patients with neurological visual impairment. As of this writing, the program now serves 15% to 20% of WBRC admissions.

The CNVR program addresses a variety of functional visual deficits, including field loss from quadronopia, hemianopia, and a constricted field. The program also serves patients with typical visual acuities to no light perception. For example, patients with hemianopic field loss may have typical or near-typical acuities but experience additional challenges to safe and effective travel because of spatial and perceptual deficits. These conditions affect not only travel, but activities of daily living, reading, writing, and other near and intermediate tasks.

Neurological vision rehabilitation has been extensively studied, although controversy remains and no single method has achieved widespread acceptance. Hemianopia is one of the most common visual disorders following brain injury (Pambakian, Currie, & Kennard, 2005; Rowe et al., 2009). Literature reviews have examined a variety of rehabilitation techniques, including prisms (Bowers, Keeney, & Peli, 2008; Peli, 2000a, 2000b; Perez & Jose, 2000; Szlyk, Seiple, Stelmack, & McMahon, 2005), vision restoration therapy (Sabel & Kasten, 2000), and a variety of methods to train compensatory scanning techniques (Diamond, 2001; Klavora & Warren, 1998; Verlander et al., 2000; Webster et al., 1984). Although the literature reviews did not yield definitive conclusions, they supported the use of scanning training (Bouwmeester, Heutink, & Lucas, 2007; Marshall, 2009; Riggs, Andrews, Roberts, & Gilewski, 2007) to address the vision rehabilitation needs of patients with field losses.

Compensatory scanning training was selected as the primary rehabilitation strategy in neurological vision rehabilitation for field loss because it complimented existing WBRC therapy in mobility and visual skills. Specifically, the

Figure 1. NVT scanner. A patient shown with a therapist in front of the light bar, with the therapist controlling the scanner and recording results on the NVT laptop.

Neuro Vision Technology (NVT) System (see www.neurovisiontech.com.au) was chosen because it was integrated seamlessly into the existing mobility program and had the additional benefit of providing hands-on training specific to brain injury. The NVT system consists of a light panel with two rows of 10 colored lights that provide the stimuli for the assessment and training of patients with field loss and/or spatial-perceptual deficits (see Figure 1). The light panel is controlled by a laptop computer running proprietary software that records demographic information, history, and assessment and training results for each patient. The software integrates this information and provides standardized instructions to the therapist on assessment and training procedures.

Assessments and training using the light panel consist of presentations of a single light and combinations of lights. The patient is asked to respond by pointing to the light or lights or naming the color or colors. The training can progress by asking the patient to describe the pattern of lights; for example, comparing the colors and patterns of lights shown on the right with those on the left. A primary intent of the training is to teach compensatory head turns into the area of deficit. As the static vision training progresses, additional paper-and-pencil exercises, such as a letter-word search, letter cancellation, reading, and other near tasks are integrated.

Upon successful completion of static training exercises, the patient continues on to the dynamic training exercises. Dynamic training emphasizes the transfer of static skills into O&M tasks. It consists of applying compensatory head turns while the patient is mobile. Dynamic training begins in a quiet hallway where the patient is asked to locate various targets. These targets are strategically placed in the patient's deficit field, which requires a head turn to detect them visually. This training progresses into more complex environments, such as stores, street crossings, and unfamiliar areas. In place of prepositioned targets, patients are asked to scan for address numbers, business signs, or other environmental targets to reinforce compensatory scanning strategies. The overall goal of dynamic training is to create a habitual head turn into the area of deficit.

A battery of assessments is provided before and after training to document the patient's progress and ensure the effectiveness of treatment. For example, assessments of the performance of a near task on pen and paper (the Rivermead Behavioral Inattention Test) are recorded, as is the performance on reading and eye-hand coordination. The NVT system records pre- and postlight panel static assessments, which are supplemented with the Mobility Assessment Course (MAC). The MAC is an indoor mobility course that requires the patient to follow directional signs for orientation to the route and to point out targets that are placed along hallway walls. The orientation signs are indicated by four directional arrows, and target identification utilizes 24 targets (colored 4 inch by 4 inch squares), placed at a variety of heights, with 12 on both the right and the left side. Scoring the MAC consists of recording the number of targets on each side that were correctly pointed out, the number of directional signs that were followed, and the total time it took to complete the route. The posttraining results of the MAC are compared to the pretraining results as a measure of improvement. These results are shared with the patients to demonstrate their progress.

Although this article focuses on neurological vision rehabilitation, it is important to note that it is only one component of the CNVR program. The purpose of the CNVR program is to integrate neurological vision rehabilitation into an interdisciplinary treatment model, thus providing a more comprehensive program. This integration is facilitated by the program's location within a tertiary medical center that provides specialized brain injury rehabilitation services (physicians, nurses, neuropsychologists, social workers, psychologists, physical and occupational therapists, audiologists, speech pathologists, recreation therapists, and other professionals). The guiding principal is to address the comprehensive needs of the patient in the most effective manner.

Case study

At the time of admission to the WBRC, Craig (a pseudonym) was a 28-year-old Iraq war veteran with PTSD, who had a TBI resulting from a high-speed motorcycle accident. He sustained a right frontoparietal lobe injury, a subdural hematoma, and nasal fracture. In addition, his TBI resulted in left-side spastic hemiparesis.

While receiving acute care at PRC, Craig participated in extensive physical therapy, occupational therapy and speech and language therapy, and worked with a neuropsychologist and a social worker. Once he was medically stable, he transitioned to WBRC and continued therapies with a physical therapist, occupational therapist, psychologist, and speech therapist.

Optometric findings for Craig at admission were a reduced visual acuity (20/80 in the right eye and 20/400 in the left eye) with homonymous hemianopia, as well as a binocular vision disorder. Craig displayed jerky saccades and pursuits, with a delayed initiation of voluntary saccades. He displayed rapid fatigue (he was unable to complete 10 consecutive saccade cycles). Despite these findings, Craig denied any changes in vision and stated that he saw the "same as before the accident." The team's treatment goals in the areas of binocular vision therapy were to improve Craig's ocular motor function, visual motor integration, speed of visual processing, and spatial awareness.

One example of a training tool that was used was the Wayne Saccadic Fixator to train Craig's eye-hand coordination, spatial awareness, and reaction times. Initially, Craig's performance was 58, 42, and 53 targets per minute while responding with his right hand, left hand, and alternating right and left hands, respectively.

A modified game of table tennis was used to address visual motor integration and ocular motility. Craig was instructed to hit a Ping-Pong ball with the paddle as many times as possible, standing in place. This exercise challenges fixation, pursuits, visual attention, concentration, and visual motor integration. It can also be practiced independently outside therapy time.

Concurrent with vision therapy, Craig received O&M assessments and training. The initial O&M assessment demonstrated problem-solving difficulties, inefficient route planning, poor identification of landmarks for orientation, and insufficient use of vision for safe and independent travel. In addition, he had deficits in depth perception, color vision, mental mapping, right-left confusion, attention; difficulty using cardinal directions (spatial reasoning); and limited independent mobility.

Craig presented with a strong inattention to the left side of his visual field. During therapy, he was easily distracted, had difficulty filtering out irrelevant environmental information, and was often argumentative. Craig insisted that he did not have problems with his vision.

During the initial MAC, Craig correctly identified 41% of the targets on the left and 54% of targets on the right. He identified all four directional signs correctly, completing the route in 257 seconds. He used a single-point support cane during ambulation of the course. These percentages were shared with him after he completed the course. It was the first time that Craig verbalized that he "may really have a vision problem." And this realization led to his agreement to continue vision therapy.

A static NVT assessment using the light panel revealed deficits in the speed of visual processing, difficulty attending to multiple stimuli, and random lateral visual scanning. Craig required verbal and auditory prompting to scan to the perimeter of his affected side. First, an NVT pretraining session showed an immediate response to instructions, with visual problem solving and a good potential for rehabilitation. Although speed of processing and attention required additional prompting, Craig was determined to regain his independence in mobility.

The NVT training goals included improving the speed of visual processing, visual-spatial problem solving, and attending to multiple stimuli in the process of changing stimuli. Craig was instructed to start his scan at the perimeter of his left field and to turn his head toward the midline. Using NVT explicitly to demonstrate his field loss to Craig provided a concrete explanation for the visual field deficits from his brain injury. An emphasis on the proprioception of the neck muscles assisted Craig in learning how far to turn his head to compensate for his field loss. Training focused on the efficient and systematic use of vision. Ongoing education regarding the visual pathways and implications of damage to the right frontoparietal lobe was provided. Cotreatment with physical therapy enabled the incorporation of balance tasks combined with compensatory scanning. Additional response tasks, such as tapping a foot and clapping hands, were added to make exercises more difficult, and distracters (such as ambient sounds and the reversal of tasks) were added to enhance attention and concentration. At this point, the instructor ceased prompting Craig during NVT training exercises.

Treatment progressed into dynamic training that included spotting targets in hallways, map reading, route planning, and strategies for memory issues and orientation. Such methods as using his camera phone to take pictures of important visual landmarks and making audio recordings for route instructions and other reminders were used. Dynamic training progressed from hallways to real-world environments, including stores, public transportation, and street crossings—all with an O&M specialist.

Craig completed a total of 18 sessions in NVT training in both static (6) and dynamic (12) environments. He showed substantial improvement over the four weeks of treatment. Gains using other training tools, such as the Peg Board Rotator, Hart Chart, Marsden ball, and additional ocular motor exercises, were recorded.

The posttraining results indicated improvement in many areas. The MAC showed Craig's 75% correct identification of both left- and right-side targets, correct identification of all directional signs, and completion of the route in 177 seconds without the use of a single-point support cane. In addition, Craig's Ping-Pong abilities increased from 7 to 94 consecutive excursions. Craig's eye-hand coordination also improved, as indicated by his performance on the Wayne Sacadic Fixator. His initial scores were 58 (right hand), 42 (left hand), and 53 (both hands) targets per minute, and his posttraining scores were 65, 50, and 58 targets per minute, respectively, for an average gain of 14%.

The final optometric examination found that Craig's visual acuity had improved to 20/20 in the right eye and 20/25 in the left eye, while his hemianopia remained unchanged. The improvement in acuity was most likely due to a combination of both vision training and correction, although we cannot completely rule out a spontaneous recovery of his central vision. Craig also demonstrated improved ocular motor function and control, smooth pursuits, improved saccades, and an increased ability to maintain a steady fixation on an object.

Although the treatment resulted in Craig's improved visual performance, perhaps the most remarkable gain was his insight into his vision loss. During this training, Craig verbalized that his vision was not the same as before the accident, and he was able to use humor to describe his loss. Jokingly, he described himself as a "TBI blind man." Despite his humor, Craig made significant improvements through the therapy he received. His therapists attributed his gain in self-awareness to the concrete, performance-based therapy that quantified his visual performance and allowed Craig to recognize the evidence of his improvement. Craig thus became aware of how poor his initial performance was compared to his performance later in the therapy process. As his therapy progressed, he was able to verbalize the skills that were necessary for him to compensate for his field loss. On a more practical level, Craig also demonstrated an improved ability to perform daily living tasks, and he was able to demonstrate safe and independent mobility. Upon his discharge, Craig received a referral for mobility training in his home community and a computer program to facilitate self-training. He has also been scheduled to return to the WBRC for additional CNVR training.

Discussion

In this article, we have described an innovative program that was designed to address the vision rehabilitation needs of service members and veterans who have sustained TBIs and associated visual impairments and dysfunctions. Although the prevalence of such vision losses is not known, the literature suggests that these losses are more frequent than is recognized by the medical and rehabilitation communities (Gianutsos, 1991; Kerkhoff, 2000). As a result, vision services are rarely provided for these patients.

The WBRC has developed a specific program that has been clinically effective. Critical to the future success of the program will be continued refinement of the neurological vision rehabilitation program and its continued integration within a comprehensive, interdisciplinary care group. Neurological vision rehabilitation is, after all, only one of many specialty areas that are needed to serve patients with severe brain injury.

Currently, patients with neurological vision loss are treated within the PRC or the CNVR program or both and are afforded neurological vision rehabilitation as quickly as their injuries permit. However, as we noted, the availability of the program has begun to generate referrals, and a waiting list of patients has developed. The challenges we face are how to provide rehabilitation to patients on the waiting list most effectively, in addition those who need outpatient services and follow-up care.

Specifically, we will need to explore if we can provide brief interventions that, in effect, provide “stopgap” interventions. Such interventions would be designed to improve the patient’s immediate safety and provide a greater level of independence until such time as the patient can be admitted for comprehensive rehabilitation. Establishing such brief interventions poses a challenge to our existing resources, and implementing them will require additional planning.

As was illustrated by the case history of Craig, rehabilitation strategies that are specifically designed to meet the unique needs of these patients can improve the patients’ awareness of their deficits, motivation, and daily function. Although we view this novel program as successful and hope that others will increase their services for TBI-related vision loss, we also recognize that it is incumbent upon programs such as this one to provide evidence-based outcomes. Toward this end, we have initiated and gained approval for additional research to assess the results of our interventions objectively.

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