CASE REPORT

Making Modifications in Vision Therapy for a Child with Cerebral Visual Impairment and Developmental Delay

Amrit Bilkhu, OD, FAAO[1]

Jennifer Fisher, OD, FAAO[1]

[1]*Herbert Wertheim School of Optometry & Vision Science at the University of California, Berkeley*

ABSTRACT

Background

Background: Children with cerebral visual impairment (CVI) and/or developmental delay (DD) have a higher incidence of oculomotor dysfunction and visual perceptual challenges, in addition to challenges with motor control and body awareness. Such disorders could negatively impact one's quality of life.

Case Summary

This case demonstrates the efficacy of modified vision therapy (VT) activities in a 5-year-old child with CVI and DD. She completes roughly 50 sessions of VT and shows significant improvements in visual tracking and visual perceptual (VP) skills.

Conclusions

This case emphasizes that children with CVI and/or DD can benefit from VT. The progress of therapy may be affected by other motor and cognitive challenges; therefore, visual modifications to standard VT procedures can improve therapy success in these patients.

Correspondence regarding this article should be emailed to Amrit Bilkhu, OD, FAAO, at **abilkhu7@gmail.com**. *All statements are the authors' personal opinions and may not reflect the opinions of the College of Optometrists in Vision Development, Vision Development & Rehabilitation or any institution or organization to which the authors may be affiliated.* *Permission to use reprints of this article must be obtained from the editor. Copyright 2021 College of Optometrists in Vision Development.* *VDR is indexed in the Directory of Open Access Journals. Online access is available at* **covd.org. https://doi.org/10.31707/VDR2021.7.4.p245**.

Bilkhu A, Fisher J. Making modifications in vision therapy for a child with cerebral visual impairment and developmental delay Vision Dev & Rehab 2021; 7(4):245-53.

Keywords: bilateral integration, cerebral visual impairment, developmental delay, sensory integration, vision therapy, visual perception

BACKGROUND

Cerebral visual impairment (CVI) encompasses visual dysfunction due to damage or a disorder of the visual pathways and visual centers in the brain. This includes damage to the pathways serving higher visual perception, cognition, and visual guidance or movement.[1,2] Sakki et al.[3] propose the following definition for childhood CVI: "childhood cerebral visual impairment is a verifiable visual dysfunction which cannot be attributed to disorders of the anterior visual pathways or any potentially co-occurring ocular impairment.". CVI falls under the category of BVI, or Blind and Visually Impaired (BVI), therefore classifying CVI in the category of BVI can help a child access educational support. CVI is the leading cause of visual impairment in children, affecting about 17% of children in the U.S alone.[1,2,4,5] Children with CVI can demonstrate a substantial level of visual processing difficulties, regardless of visual acuity or visual field quality.

The definition of CVI remains vague and different terminologies are applied to this disorder. This can lead to lack of communication and inconsistencies in treatment. More recently, in addition to reduced visual acuity and/or visual fields, the inclusion of a broad range of visual and ocular dysfunctions is suggested. This includes abnormalities associated with visual pathways, oculomotor dysfunction, cortical problems, and visual information processing abnormalities (dorsal and ventral stream processing pathways).[6] For example, a child with brain injury and severe deficits in functional use of vision (visual motor, route finding) may have normal visual acuities. This child may still benefit from a diagnosis of CVI, and therefore receive management strategies. There have been suggestions to expand the CVI term to include wider visual deficits, since children with CVI have great difficulty in everyday visual behaviors beyond visual acuity. Furthermore, the terms cerebral and cortical have been used interchangeably. Sakki et al.[3] write that cerebral rather than cortical is preferred, since subcortical damage of the posterior visual pathways is common.

Common causes of CVI include conditions which damage various areas of the cerebral cortex responsible for higher visual processing such as cerebral palsy and seizure disorders; conditions which particularly damage the parietal lobe, in addition to hydrocephalus, hypoxic-ischemic encephalopathy, developmental brain abnormalities, central nervous system infections and head trauma.[7,8] The parietal lobe accompanies the dorsal stream pathways of the occipital lobe, which both play an integral part of visual development. These pathways are responsible for analyzing a complex visual scene, selective visual attention, determining visual coordination, visually guided body movements, and rapid eye movements from the frontal eye fields.[9,10] Therefore, CVI patients often have challenges with *functional vision*[1,5,6,11] including laterality/directionality, visual guidance and spatial skills, visual-motor-integration, visual perception (VP), and simultanagnosia, in addition to *visual function* disorders (e.g., reduced visual acuity, visual field loss, large refractive errors, reduced contrast sensitivity, and dysfunctional oculomotor, binocular, and/or accommodative systems).

Inadequate development of the parietal lobe region also influences other developmental delays (DD) including late onset of motor, speech, behavioral, and cognitive skills. These fundamental skills influence visual development in the early stages of life. For example, gross motor coordination is imperative for children to develop fine oculomotor control, bilateral integration, body and spatial awareness, and visual motor integration. Oculomotor control allows a child to visually explore their environment rather than relying on motor movements. Bilateral integration skills allow one to acknowledge their midline and differentiate between left and right, while body and spatial awareness creates awareness of one's body in space before localizing other objects relative to themselves. Lastly, visual motor integration skills are responsible for transitioning from motor to visual learning as the child develops. Therefore, children with suspected CVI and known DD require a thorough assessment of visual and developmental skills to understand how it may impact the child's quality of life and their learning potential.

Vision therapy (VT) has shown efficacy for many visual and perceptual dysfunctions in children; however efficacy for patients with CVI and DD is varied. Some practitioners may believe that a child with CVI and DD isn't a candidate for VT based on the severity of their delayed development. This case challenges that assumption. VT is possible in children with CVI and DD; however, the program requires more modifications to accommodate the patient's specific needs. The following case involves a young child with CVI and DD with extensive VP challenges, and how modifications to standard VT activities allowed her to successfully improve her ocular motility and overall visual perceptual skills.

CASE REPORT

JS, a 4-year-old female presented for a comprehensive binocular vision and VP skills assessment. JS was diagnosed with congenital cortical dysplasia and suffered an onset of seizures after multiple vaccinations at 8-weeks-old. Her mother made observations of JS's irritability and loss of eye contact 24 hours after her vaccinations, therefore JS's mother believes the vaccinations contributed to onset of seizures. There was no medical documentation to confirm these suspicions. She underwent a left occipitaltemporal-parietal lobe resection at 10-months-old for management of intractable epilepsy, resulting in a right homonymous hemianopia among other significant delays in her development. JS has been enrolled in occupational therapy since her infant and toddler years, which improved her gross and fine motor abilities. She is also enrolled in a social skills therapy program. She was enrolled into an orientation and mobility therapy program until 3-years-old; she was able to ambulate well and thus, graduated from the program. She has struggled with learning, such as learning her alphabets and numbers. At the time of the initial assessment, JS's family had chosen to delay her start in kindergarten. JS is currently taking Zonigram 25mg twice daily for maintenance of her seizures. Her mother notes that she often sees JS's right eye going out daily.

Diagnostic Data

On examination, unaided distance visual acuity with single Lea optotype was OD 20/25 and OS 20/20. Pupil testing was within normal limits in both eyes. Colour vision was normal in both eyes, measured via Portnoy Plates; a modified colour vision test that identifies protan, deutan, and tritan colour defects and their severity.[12] Confrontation visual fields confirmed the right homonymous hemianopia. Cover test revealed a 16^ intermittent right exotropia with high frequency at distance, with the magnitude increasing to 20^ at near. Dry retinoscopy revealed OD+0.50 DS and OS +0.50 DS. Ocular motility testing showed age-appropriate fixation and saccades, but inaccurate pursuits with mild losses of fixation in both eyes and in all directions. JS had fusion at all distances using Beren's 3-Figure pediatric flashlight and gross depth perception on the Stereofly test. NPC break was at 15 cm with recovery at 18 cm. Monocular estimation method retinoscopy results showed +0.50 D lag of accommodation in each eye. She was unable to perform vergence ranges or accommodative testing due to inattention.

Anterior segment findings, tactile intraocular pressures, and posterior segment findings were within normal limits for each eye.

VP tests were administered to determine JS's strengths and weaknesses in her VP and cognitive skills. The Developmental Eye Movement (DEM) test assesses simulated reading eye movements for speed and accuracy while calling out numbers to evaluate rapid automatic naming skills, horizontal tracking, visual processing speed, and spatial planning. A modified DEM was performed at the initial assessment, where three to four large coloured stickers were placed in evenly spaced columns or rows. JS was instructed to point to each sticker, in order from top to bottom or left to right, to exclude a verbal component. The original DEM was administered later as she progressed through the VT program. The Motor-Free Visual Perception Test (MVPT-3) and the Test of Visual Perceptual Skills Test (TVPS-4) address seven subcategories of VP. The test items exclude complex responses such as speaking, writing, and drawing; only a pointing response is required among choices. The LEA 3D 4-piece puzzle is a pediatric test for visual motor integration, where the child must insert puzzle pieces into a board in the correct orientation while observations are made on hand function and numbers of attempts. The Beery Visual Motor Integration (VMI) test measures one's ability to integrate visual information and motor proficiency by coping forms onto a blank space with no erasures under timed conditions. The Test of Visual Analysis Skills (TVAS) assesses spatial planning skills by presenting a pattern on a dot-grid plane and asking the child to replicate the pattern on an empty grid. The Piaget Left/Right Awareness test evaluates laterality by the child's ability to identify left or right from their own perspective, and other objects in relation to each other. The summary of findings displays each VP test and the corresponding visual skills they assess are listed in Table 1.

Table 1: Clinical findings before and during VT

VP Diagnostic Test	Pre-VT	Post-VT #30	Post-VT #50
Horizontal Visual Tracking			
Developmental Eye Movement Test (DEM)	UTC (modified DEM)	Vert: UTC Hor: -14 SD Err: N/A Rat: N/A	Vert: -7 SD Hor: -3 SD Err: 0 SD Rat: 0 SD
Visual Perception			
Motor-Free Visual Perception Test (MVPT-3)	<1st %ile	10th %ile	19th %ile
Test of Visual Perceptual Skills (TVPS-4)	UTC	DIS: 50th %ile MEM: 25th %ile SPA: 5th %ile FOR: 9th %ile SEQ: UTC FIG: UTC CLO: UTC	DIS: 37th %ile MEM: 27th %ile SPA: 30th %ile FOR: 37th %ile SEQ: 75th %ile FIG: 25th %ile CLO: 30th %ile
Visual Motor Integration			
LEA 3D 4-piece Puzzle	UTC even with assistance	Completed with verbal guidance	Completed without verbal guidance
Beery VMI	UTC	VMI: 10th %ile	VMI: 25th %ile
Spatial Awareness and Spatial Planning			
Piaget L/R Awareness	<5 AE	<5 AE	10 AE
Test of Visual Analysis Skills (TVAS)	UTC	Kindergarten GE	Kindergarten GE

Legend: UTC – Unable To Complete; **SD** – Standard Deviation; **N/A** – Not Applicable; **%ile** – Percentile Rank; **AE** – Age Equivalent **GE** – Grade Equivalent

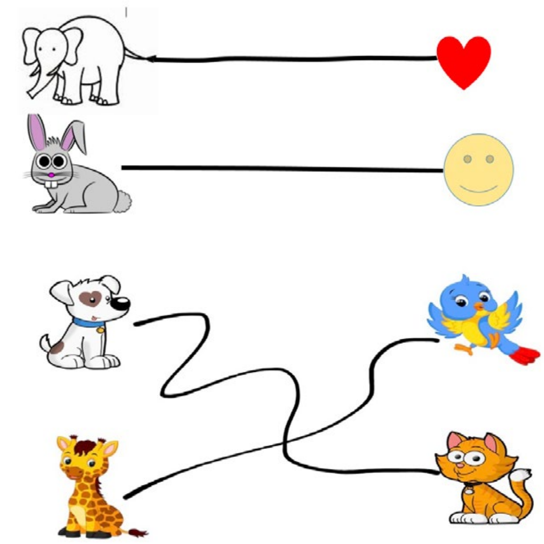
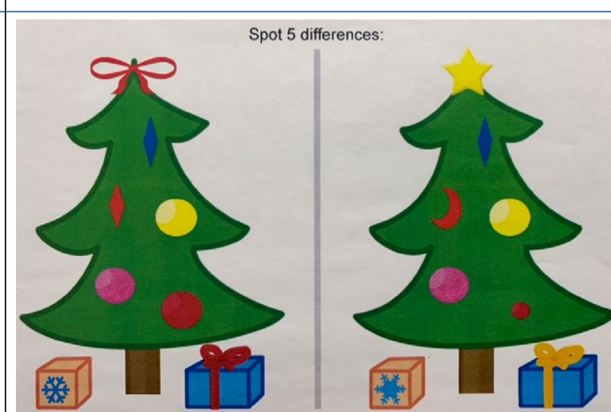
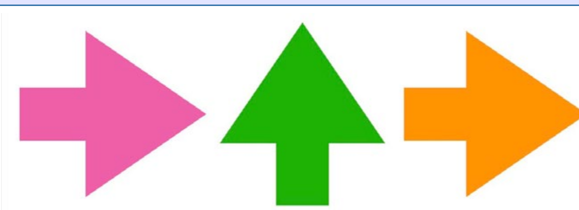
Diagnosis

JS was found to have significant visual perceptual difficulties in the following areas:

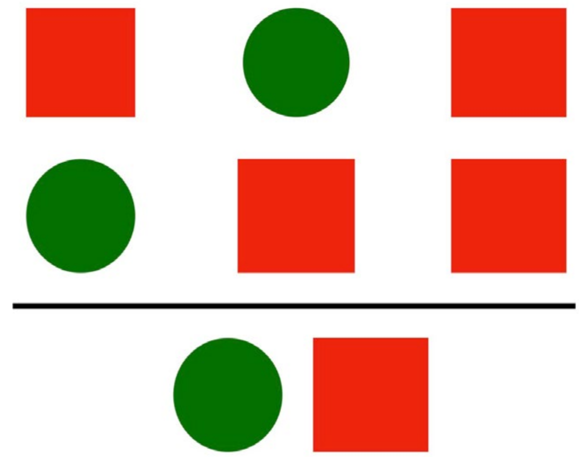
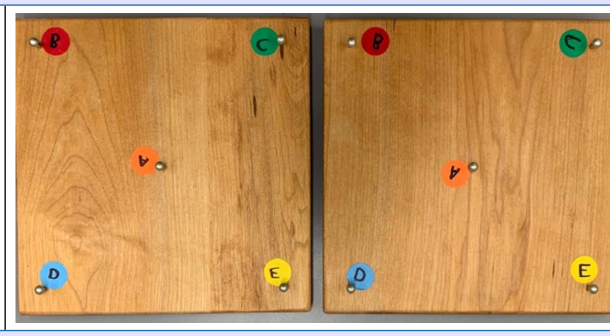
- Horizontal tracking
- Spatial planning and spatial awareness
- Laterality and directionality difficulties
- Visual motor integration difficulties
- Visual Closure, Visual Spatial Relations, Visual Memory, Visual Figure Ground difficulties

CVI was diagnosed in JS based on her reduced visual functions from the extensive list of VP deficits, her history of cortical dysplasia and seizures, and observations of common CVI visual behaviours[9,13] (e.g., lacks visual curiosity, performs best when one sensory input is presented at a time, delayed visual responses, inaccurate visual-motor responses). Saunders et al.[14] describe comprehensive methods for diagnosing CVI. The most common way of diagnosis was on the basis that her visual dysfunctions could not be accounted for based on ophthalmological examination findings, and her significant medical history. In addition, other suggested tools to diagnose include neuroimaging, structured clinical history-taking, and VP testing. It is recommended that a multi-assessment approach using many factors can be most beneficial to the patient. Since multi-assessment is recommended, a multi-disciplinary approach in aiding in the diagnosis is suggested. Thus far, we are the main professionals that have given JS the diagnosis of CVI. Furthermore, screening inventories for CVI[15-17] which ask parents or caregivers behavioural and developmental questions are often used to support the diagnosis as well, however they were not used in this case. JS did demonstrate lack of object and facial processing (factor 1 in the Flemish CVI Questionnaire), which is the most significantly distinguishing factor between children with and without CVI. For example, she could not match simple shapes

Table 2: Modified VT activities

VT Activity	Modification	Image
Pursuit Tracking		
Line Mazes	Use finger to help guide in the beginning. Start with separate straight lines, crossing lines, then busier curved lines. Rationale: Sensory integration and reduce visual crowding.	
Horizontal Saccadic Tracking		
LEA, Number, or Letter Tracking	Point to, or circle the target with a marker, from left to right. Start with one row with 2-3 targets, then add more rows. Rationale: Reduce visual crowding.	Circle the A in each line from left to right. A C A A B A C A B D A D
Spot the Difference	Find difference between two pictures. Start with large colored images, then more detailed. This also emphasizes visual figure ground skills. Rationale: Reduce visual crowding.	
Bilateral Integration / Directionality / Laterality		
Directional Arrows	Clap with both hands in the direction of the arrows. Start slow, then add a faster beat or more arrows. Rationale: Incorporate bilateral integration.	

(continued)

Modified Visual Motor Form C	One at a time, index fingers touch corresponding shapes along each row. Start slow, then add a faster beat. Rationale: Incorporate bilateral, sensory, and visual motor integration.	
Spatial Planning		
Geoboard Rubber Band or Rosner Dot Patterns	Point to matching pegs. Then copy geometric patterns on boards using rubber bands. Or use thick markers when copying patterns on Rosner paper grids. Rationale: Reduce crowding and incorporate sensory integration using rubber bands.	
Sequencing		
Color Sequencing	Place colored tiles in the same sequence as presented. Start with two colors, then add more. Rationale: incorporate visual sequential memory.	

on the LEA 3D four-piece puzzle activity, and she had significant lack of eye contact. Overall, JS demonstrated multiple factors that support her diagnosis of CVI: 1) significant visual processing deficits unexplained by ophthalmological exam, 2) lack of positive visual behaviors, and 3) significant medical history with neuroimaging.

In addition, JS was diagnosed with an intermittent alternating exotropia, convergence insufficiency, right homonymous hemianopia, and simultanagnosia secondary to CVI based on observations and VP testing results. Although we also addressed her intermittent alternating exotropia in therapy, for the purposes of this paper, we will emphasize modifications made in improving her VP skills.

Prognosis and Therapy Plan

A course of VT was recommended for an estimated 40-50 weeks to address JS's VP challenges and to strengthen her oculomotor and binocular skills. Her prognosis was guarded as limitations were set by the occipital-temporal-parietal lobe resection. In addition to VT, certain recommendations for home and academic accommodations were provided to advocate for JS and enhance her learning. The following are just a few examples of these recommendations:

- Encourage a multisensory learning environment where JS can taste, smell, see, hear and manipulate objects related to the lessons she is learning.

- Use a line guide or finger tracking when learning to read to compensate for deficient tracking skills.
- Use wide-ruled paper with larger spacing and font size to reduce visual clutter, and to compensate for spatial planning and visual figure ground challenges.
- Pairing visual instruction with auditory instruction when appropriate.
- Allowing additional time on classroom assignments to compensate for delayed visual processing speed.
- Present information on the left side to accommodate for her visual field loss.
- Provide access to a Teacher of Students with Visual Impairments (TVI) who provide direct special education services specific to vision loss.
- Continue working with an occupational therapist to address letter orientation and handwriting. Use tactile letters, flashcards, or tracing letters in sand to further enforce her sense of correct orientation.

Modifications Made in VT Activities

Emphasis during therapy was placed on body awareness and spatial planning, laterality, visual motor integration, saccadic and pursuit eye movements, and gross vergences. Many of the modified activities performed incorporated bilateral and sensory integration, and reduced visual crowding. Examples of modified VT activities throughout JS's VT program are listed in Table 2.

Tracking activities included modified Groffman line mazes and horizontal letter tracking. Modifications were made by using larger and less crowded worksheets. Simple line mazes with pictures at the start and finish are a great way to encourage pursuits, visualmotor-integration, and sensory integration skills. The child uses a finger to follow the line and state what pictures connect together. Lines become more curved and crowded to increase difficulty. After a few rounds, the child is encouraged to visually assess the lines and determine which pictures connect before using their finger to confirm their answer. Modified letter (or symbol) tracking involves one row of two to three large spaced out letters on paper in order to reduce visual crowding. The child is encouraged to start from the left side and touch, cross out, or circle the letter they are searching for. To increase difficulty, add more letters to each row, or add more rows.

Spatial planning skills were exercised with geoboards and rubber bands. Starting with a 5-peg board with labelled coordinates from 1-5 or A-B can reduce visual crowding for the child. The easiest level of activity involves the therapist pointing to a coordinate on the board and having the child touch the matching coordinate on their board. Simple lines or shapes are then created on the board using rubber bands, which the child has to copy on their board using spatial mapping skills. Using rubber bands encourages sensory integration.

Visual perceptual skills are trained through directional arrows. This is a great activity that encourages bilaterality, crossing the midline, directionality and horizontal tracking, and can be modified in many ways. Start with two to three large, brightly coloured arrows in one row facing different directions. Space these arrows out to reduce visual crowding. The child then claps in the direction of the arrows, moving from left to right. Adding a slow metronome or moving to the beat of a song will emphasize auditory processing.

Visual memory activities performed during therapy included colour sequencing. A large coloured tile is placed in front of the child for a few seconds, and then hidden. The child then places a matching coloured tile on their table. To increase the level of difficulty, add a second coloured tile making a sequence. The longer the sequence becomes, the more challenging it is for the child to remember. To further modify this activity, each colour can be associated with food *(for example; yellow for banana or red for apple)* to assist the child's memory when recreating the sequence.

Visual figure ground activities include spotting the difference where one has to identify particular objects within a larger image. This is also an excellent saccadic activity that encourages the child to look between two fairly similar colourful pictures to identify any obvious differences. Modifying this activity by starting with simple images containing two to three objects only will reduce visual crowding.

Progress of Visual Perceptual Changes

VP test results throughout the course of JS's VT program are listed in Table 1. After 50 VT sessions over a period of two years, JS enhanced her VP skills compared to initial findings. Throughout VT, JS developed compensatory strategies to her vision deficits. This was accomplished through repetition and multi-sensory feedback to help accomplish a task. Findings were within age-expected norms for tests involving visualmotor-integration, spatial awareness, and all subcategories of VP skills on the TVPS-4 and MVPT-3. Horizontal tracking skills on the DEM were still below norms, however her performance overall had significantly improved compared to initial testing. Over time due to her improved visual perception, JS has been able to recognize her errors more readily, track and verbalize objects on a page from left to right more confidently without a line guide, attend to more complex tasks with multiple objects on the page, and incorporate auditory or motor components to visual tasks. These improvements have enhanced JS's learning and reading abilities throughout her homeschooled kindergarten program, which she enrolled into at the age of five. Her mother also reported she became more engaged in learning activities at home. It was recommended to continue VT with emphasis on horizontal tracking movements and vergence activities, while still incorporating VP skills within these modified activities. Appropriate recommendations for learning accommodations would be continuously updated as needed.

CONCLUSIONS

This case emphasizes that children with CVI and visual perceptual deficits can benefit from vision therapy. The progress of therapy may be affected by other motor and cognitive challenges, therefore, visual modifications to standard vision therapy procedures can improve therapy success in these patients.

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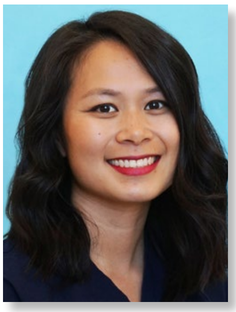
CORRESPONDING AUTHOR BIOGRAPHY:
Amrit Bilkhu, OD, FAAO
Bolton, Ontario, Canada

Dr. Bilkhu graduated from the Illinois College of Optometry in 2019, and completed a Vision Therapy and Rehabilitation residency at the UC Berkeley School of Optometry in 2020. Throughout her education, Dr. Bilkhu has become skilled in helping patients with amblyopia, strabismus, binocular vision dysfunction, and visual perceptual challenges. In addition, she is the creator and co-host of the popular optometry podcast, Four Eyes. Dr. Bilkhu interviews influential optometrists who are making a difference in the profession, and shares cases or resources that provide value to optometrist's clinical knowledge.



AUTHOR BIOGRAPHY:
Jennifer Fisher, OD, FAAO
Berkeley, California, USA

Dr. Fisher completed her Doctorate of Optometry at UC Berkeley and the Irwin B. Suchoff residency in vision therapy and rehabilitation at the State University of New York, College of Optometry. Dr. Fisher is an Assistant Clinical Professor in the Binocular Vision clinic at the Herbert Wertheim School of Optometry and Vision Science at UC Berkeley. She works with patients with learning-related vision issues, strabismus, amblyopia, and those that have suffered acquired brain injuries.