Virtual Reality Treatment for Complicated Mild Traumatic Brain Injury: a Case Study

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***Abstract*—Individuals with complex injuries often require innovative treatment techniques, such as virtual reality, to address rehabilitation goals. A Canadian Armed Forces member diagnosed with a complicated mild traumatic brain injury completed 10 virtual reality sessions over 15 weeks. Virtual reality sessions included scenarios to provide both physical and cognitive challenges appropriate to the participants' needs and ability for each session. After 10 sessions, post concussion symptoms were improved and the patient was able to manage more visual stimuli without increasing headache severity. Additionally, return-to-work duration and frequency was increased. This treatment modality provided ability to quickly and easily adapt intervention to address our patient's unique needs while providing a controlled and focused rehabilitation environment. Virtual reality should be considered as an adjunct rehabilitation tool for patient's presenting with complex injuries and/or delayed recovery.**

Keywords—Virtual reality; mTBI; treadmill; rehabilitation

I. Introduction

Majority of individuals sustaining a mild traumatic brain injury (mTBI) have a full recovery of symptoms within 3 months. Approximately 25% of Canadian Armed Forces (CAF) with deployment-related mTBI diagnoses experienced persistent symptoms, which may lead to delayed recovery [1]. Treatment may be further compounded by additional co-morbidities commonly observed in military service members, including Post-traumatic Stress Disorder (PTSD), depression and anxiety. As a result, the patient and their health care team may have greater difficulty achieving significant functional gains with conventional rehabilitation programs and may reach a plateau in recovery.

Virtual reality (VR) is one treatment modality that offers a safe environment to deliver innovative therapy and to identify deficits difficult to observe in a clinical setting. CAF physiotherapy program often incorporates VR treatment to support patient care, especially when rehabilitation goals are challenging to accomplish using standard rehabilitation program.

Previous research and case studies reported promising results after use of VR in treating individuals with mTBI [2, 3]. However, few studies are available in the literature on mTBI cases with complex symptomatology. The purpose of this case study is to describe a virtual-reality based clinical intervention for treating a CAF service member diagnosed with complicated mTBI.

II. Methods

A. *Patient History*

The patient was a 50-year-old female Canadian Armed Forces (CAF) service member, diagnosed with a complicated mTBI. Initial post-concussion symptom score was 73/132 (SCAT-3) and headache severity score was 69/78 (HIT-6). Symptoms continued to worsen over the next four weeks and the patient was unable return to work. The patient was also diagnosed with PTSD and developed right side neck and shoulder pain, which increased the complexity of her mTBI. An interdisciplinary team followed the patient regularly, and consisted of a treating physician, physiotherapist (PT), occupational therapist (OT), mental health care provider (MH) and physiatrist. The patient completed 12 sessions of standard physiotherapy care over 8 months, which included education, planning and pacing strategies, visual and balance training, cardiovascular exercise, and manual therapy. After 8 months of standard care, minimal improvements were observed, and the treating physiotherapist and physiatrist decided to incorporate VR to decrease photosensitivity, to increase right upper extremity range-of-motion (ROM), and to increase endurance and confidence of dual-task walking with high visual stimuli. The patient also received 2 Depo-Medrol injections to treat right upper quadrant pain prior to initiating VR treatment.

B. *Clinical Impression*

At the time of VR treatment, the patient presented with a SCAT-3 symptom score of 61/132 and HIT-6 score of 65/78. She reported returning to work 2 hr per week and preferred to stay at home. The patient wore blue-tinted sunglasses daily to help manage symptoms and required a driver to attend VR sessions. During the first VR session, the patient's movements were extremely slow and she was unable to tolerate minimal surface and visual stimuli. She preferred very slow gait speeds (0.3-0.4m/s) when walking with or without normal visual flow. Visual motion posterior-to-anterior was identified as most difficult while performing balance tasks. Additionally, upper body and neck movement appeared effortful and the patient demonstrated characteristics of kinesiophobia and chronic pain. In addition to reduced upper extremity motion, the patient exhibited reduced ability to shift weight onto the right limb. Furthermore, the patient adopted compensatory strategies to minimize frontal plane motion. Therefore, weight shifting activities, arm reaching tasks, and anterior-to-posterior motion were incorporated into VR therapy.

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TABLE I. SUMMARY OF VIRTUAL REALITY INTERVENTION USING THE COMPUTER ASSISSTED REHABILTIATION ENVIRONMENT (MOTEKFORCE LINK, THE NL).

	Sessions 1-3	**Sessions 4-6**	**Sessions 7-10**
Photosensitivity	Level walking scenarios in dark or normal lighting while wearing sunglasses.	Level and non-level walking scenarios in dark or normal lighting without wearing sunglasses.	Level and non-level walking scenarios in normal lighting without wearing sunglasses.
Endurance and confidence to busy environments with high visual stimuli	Standing and level walking scenarios with limited visual stimuli, such as, slow moving objects in environment, minimal visual flow, and visual perturbations.	Standing with small surface perturbations with more visual stimuli, such as, normal visual flow, faster moving objects in environment, and visual perturbations with focus in posterior-to-anterior direction.	Walking with balance challenges and greater cognitive demands, such as, visual-vestibular mismatch or cognitive tasks (e.g., math, Stroop, letter association).
Upper right extremity range of motion	Weight shifting activities.	Weight shifting activities with arm reaching tasks.	Level walking with arm reaching tasks.

C. *Outcome Measures*

SCAT-3 and HIT-6 were evaluated again after VR sessions. Within session outcome measures were selected to assess the VR based intervention, including treatment time, recovery time, simulator sickness symptoms, and dizziness. Recovery time was the self-reported time to return to baseline symptom following the treatment session. Dizziness was rated on a 10-point Likert scale and symptoms of nausea, oculomotor, and disorientation were rated using the Simulator Sickness Questionnaire (SSQ).

D. *Intervention*

The patient attended 10 VR sessions over 15 weeks that consisted of therapist-patient discussion, setup time, rest breaks, and treatment. The patient continued to attend regular PT, OT and MH treatment sessions (approximately 2 hr per week). Challenging VR therapeutic environments were created through the use of scenarios to add both physical and cognitive challenges appropriate to the participants' needs and ability for each treatment session (Table I). Supplemental home-based activities were also recommended to address challenges faced during VR sessions, such as practicing weight shifting on level and slope surfaces. After each session, the patient rested to reduce symptoms before traveling. Halfway through VR sessions the patient received another Depo-Medrol injection.

III. RESULTS AND DISCUSSION

Treatment time ranged from 10-14 min (Table II). Simulator sickness symptoms and dizziness were greater post treatment, and greater scores often resulted in longer recovery times or return to baseline following the VR treatment. Mindfulness strategies were useful in reducing dizziness and nausea symptoms during rest breaks. Assessing symptoms within sessions helped guide activity intensity and duration to ensure the patient was challenged sufficiently to promote neuroplastic change.

The patient quickly adapted to walking the VR environment with normal lighting and was able to complete treatment without sunglasses after 4 sessions. Right upper extremity ROM was also quickly addressed and normalized within 3 sessions. Although improvement of right upper quadrant function was largely attributed to pharmacological treatment, VR activities helped patient engage and optimize arm movements. Halfway through sessions, the patient reported she felt more engaged in her rehabilitation, improved ability to concentrate and maintain conversation, and only wore sunglasses for sunny days with snow on the ground. As a result, she increased working hours to 2 hr twice per week and was able to drive to and from VR sessions.

TABLE II. SUMMARY OF WITHIN SESSION OUTCOME MEASURES.

Session #	**VR Time (min)**	**SSQ (/48)**		**Dizziness (/10)**		**Recovery Time (hr)**
		Pre	**Post**	**Pre**	**Post**	
1	12	4	11	2	6	≤24
2	11	4	10	0	5	≤12
3	14	3	16	0	6	≤12
4	10	7	16	0	0	≤8
5	10	4	17	0	6	≤8
6	12	3	27	0	8	≤48
7	10	5	12	0	4	≤24
8	11	3	7	0	1	≤12
9	12	3	9	0	2	≤12
10	12	5	21	2	3	≤12

After 10 sessions, SCAT-3 symptom score decreased to 42/132, and although HIT-6 score was slightly smaller 61/78, the patient was able to tolerate busier environments at faster gait speeds (0.68m/s) without increasing headache severity. She also reported improved ability to use a computer, which allowed her to increase working hours to 3 hr twice per week. VR provided the ability to quickly and easily integrate balance and sensory tasks to target rehabilitation goals and to progressively challenge the patient during each session. VR was considered a catalyst for recovery and should be considered in combination with a standard rehabilitation program for patients with complex mTBI when minimal improvement is obtained during standard therapies.

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