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Virtual Reality in COVID-19 Stroke Rehabilitation: Preliminary Outcomes

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***Abstract*—**Background: There is growing evidence that Cerebral Vascular Accident (CVA) can be a consequence of COVID-19 infection. Understanding novel treatment approaches is important in optimizing patient outcomes. Case: This case explores the use of Virtual Reality (VR) in the treatment of a 23-year-old COVID-positive female presenting with left hemiparesis in August 2020. Imaging showed right globus pallidus, thalamus, and internal capsule ischemic stroke. Conventional rehabilitation was started two weeks later, with VR included. This game-based VR technology developed for stroke patients was based on upper extremity exercises and functions for stroke. Physical examination showed left hemiparesis with muscle strength 3/5 in the upper extremity and 4/5 in the lower extremity. The range of motion of the shoulder was 90-100 degrees. The speech exam showed a mild decrease in fluency. Mild lower lip dynamic asymmetry was seen. Babinski was positive on the left. Gait speed was decreased (75 steps per minute). Intervention: Our game-based VR system was developed based on upper extremity physiotherapy exercises for post-stroke patients to increase the active, voluntary movement of the upper extremity joints and improve the function. The conventional program was initiated with active exercises, shoulder sanding for joint ROMs, walking shoulder, shoulder wheel, and combination movements of the shoulder, elbow, and wrist joints, alternative flexion-extension, pronation-supination movements, Pegboard and Purdo pegboard exercises. Also, fine movements included smart gloves, biofeedback, finger ladder, and writing. The difficulty of the game increased at each stage of the practice with progress in patient performances. Outcome: After 6 weeks of treatment, gait and speech were normal and upper extremity strength was improved to near normal status. No adverse effects were noted. Conclusion: This case suggests that VR is a useful tool in the treatment of a patient with COVID-19 related CVA. The safety of developed instruments for such cases provides approaches to improve the therapeutic outcomes and prognosis as well as increased satisfaction rate among patients.

***Keywords*—**COVID-19, stroke, virtual reality, rehabilitation.

I. Introduction

COVID-19 has affected millions around the world since its initial spread in 2019. COVID infections have been linked to a wide range of clinical impairments, particularly in the respiratory system [1], [2]. It has been noted that there is often an increase in the complexity of sequelae such as CVA, resulting in a poorer prognosis than usual [3]-[5]. Patients may be resistant to conventional modalities of treatment, resulting in a greater mortality rate [6], [7]. While diabetes mellitus, hypertension, and renal/pulmonary diseases are typical pre-existing diseases [6]-[8], some attention to less common issues such as neurological impairment is required [8]-[10]. COVID-19 has been found in neurological tissues including microvascular and glial samples as well as cerebrospinal fluid [11]. Acute and toxic encephalitis are among the complications of COVID-19 infection in central nervous system [12], [13], leading to ischemic alterations in neurons and other neurological tissues [14]-[16]. Nearly 25% of patients with COVID-19 have clinical involvement of the central nervous system leading to poorer prognosis and increased morbidity and mortality in those cases [17], [18]. CVA is a relatively common co-morbidity with COVID-19 in approximately one-third of cases. When CVA occurs concurrent with COVID-19 it is accompanied by a 6.7-fold higher mortality rate [19]. Of some concern, this is typically seen in young adults [20]. It is important that these patients have access to more effective therapeutic modalities in addition to conventional methods [21]. VR is a newly developed treatment option in patients with CVA [22], [23]. For this study, we designed and developed an exclusive game-based approach for post-CVA patients to assess the efficacy in the COVID-19 population.

II. Case Presentation

The patient was a 23-year-old female who presented with sudden left hemi-paresis on 22 July 2020. On arrival to the emergency ward, her vital signs, heart and lung exam were normal. She had normal mental status exam with Glasgow Coma Scale which was 15/15. Facial movements were normal except for the lower lip where mild dynamic asymmetry was seen, and she had mild dysarthria. The right side of the body was completely normal but the left hemiparesis was apparent with left upper extremity force of 3/5 and left lower extremity force of 4/5. Babinski sign was positive on the left side. Gait exam showed mild balance deficit. She had been experiencing an occasional dry cough in the previous 7 days. The past medical and family history was negative. She did not smoke.

ECG showed normal sinus rhythm. Chest x-ray was normal. Brain MRI without contrast showed sub-acute ischemia of the right globus palidus, internal capsule, and thalamus (Fig. 1). A computerized tomography (CT) scan of the lungs (spiral without contrast) showed no abnormal density and no evidence of active infection. Also, trachea and bronchi diameters were normal and no pleural fluid was accumulated. The heart, bones and lymph nodes were also normal (Fig. 2). She underwent brain CT angiography which was reported as normal. Cervical Doppler ultrasound showed no abnormality. Brain CT angiography, cervical Doppler, physical examination, and electrocardiogram results were normal. Trans-thoracic

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Echocardiography (TTE) showed normal function valves with good ejection fraction. Trans-esophageal Echocardiography (TEE) showed no abnormality like patent foramen oval (PFO) or other related abnormality. Lab data showed lymphopenia with high C-reactive protein (CRP) and mild anemia was found. PCR for COVID-19 was done which was positive.

Fig. 1 Magnetic resonance imaging depicting right globus pallidus, internal capsule, and thalamic signal abnormalities: T2 and FLAIR hyperintense, matched with diffusion restriction. The findings are consistent with sub-acute ischemic stroke in mentioned areas

Based on the findings noted above, the patient was diagnosed with "cryptogenic stroke" (a brain infarction not clearly attributable to a different etiology despite extensive investigation).

Physiotherapy program commenced for her in August 2020 at a stroke rehab clinic. Our game-based VR system was developed based on upper extremity physiotherapy exercises for post stroke patients to increase the active, voluntary movement of the upper extremity joints and improve the function. The conventional program was initiated with active exercises, shoulder sanding for joint range of motion (ROM), walking shoulder, shoulder wheel, and combination movements of shoulder, elbow, and wrist joints, alternative flexion-extension, pronation-supination movements, Pegbourd and Purdo pegboard exercises. Also, fine movements included smart gloves, biofeedback, finger ladder, and writing. The

difficulty of the game increased at each stage of the practice with progress in patient performances.

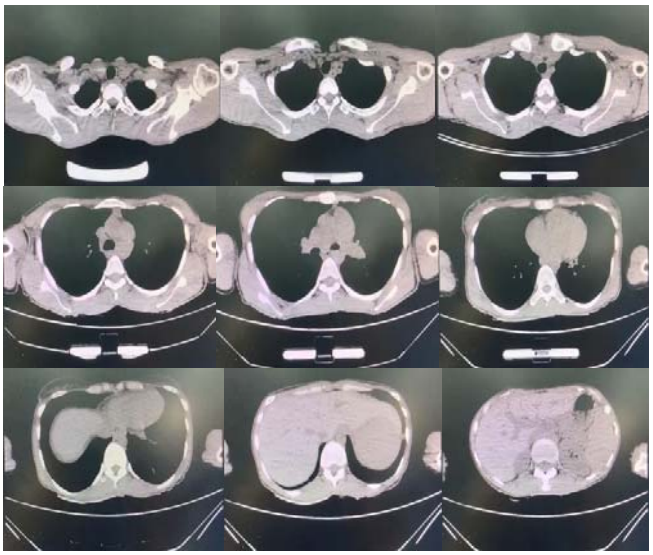

Fig. 2 CT scan of the lungs (spiral without contrast) with no abnormal density and no evidence of active infection: Also, trachea and bronchi diameters were normal and no pleural fluid was accumulated; the heart, skeletal part, and lymph nodes were also in normal status

In the game-based products, the patient sat in front of a monitor in order to move the upper extremity according to the instruction of the advanced-prepared specific computer game. She was instructed to grasp balls of different colors that were on the perimeter of a circle, hold them and then throw them into the basket of the same color at the bottom of the screen. We designed and developed our exclusive VR game-based rehabilitation product based on upper extremity rehabilitation assessments for post stroke patients to increase the ROM in the shoulder, elbow and wrist joints.

The difficulty of the game increases as the stages go on and the patient is rewarded after every successful movement. The game had a display of a numbers that was the same color as the target ball in the center of the circle. The patient had to figure out that the ball (or number) was to be grasped at that hour and was rewarded after every successful movement.

Following six weeks of conventional rehabilitation and VR recovery program, she was able to speak fluently again. A full recovery was seen in her upper extremity power, and her gait improved to near normal (103 steps per minute).

III. Discussion

This case study showed encouraging outcomes for the addition of VR in a young patient with COVID-19 and concurrent CVA. The first report of acute CVA in COVID-19 cases showed an incidence rate of 2.34% by Mao et al. [24], and since then, multiple studies have focused on the clinical course and treatment modalities in affected cases. The efficacy of VR as a newly developed therapeutic modality has previously been established in stroke without COVID-19. In a meta-analysis by Mohammadi et al., 14 papers were reviewed and among them, 13 experimental groups used VR in combination with conventional therapy. The findings indicated that VR when combined with conventional therapy, was superior to conventional rehabilitation alone in patients with CVA [22]. In an interventional study by Fishbein et al., 22 cases with CVA were enrolled in a similar program. The authors concluded that VR-based treatment could improve walking and balance function in people following stroke and it was suggested that combining conventional therapy with VR in training sessions would improve performance by virtue of improvement of simultaneous multiple tasks [23].

There are some studies addressing the role of VR in COVID-19 cases. Smith et al. [25] noted that the high applicability and good outcomes of VR, which may have increased the patients' adherence to treatment in COVID-19. As noted by Singh et al. [26], VR has the advantage of decreased face-to-face interactions between clinicians and the COVID-19 patients. Additionally, promising efficacies were reported in COVID-19 cases with background malignancy using VR by Tashkandi et al. [27] among Canadian patients. A study by Appireddy et al. [28] demonstrated that a vast majority of patients with neurological diseases required long-term therapy. The use of telemedicine methods such as VR can help to improve social distancing as noted by Montovani et al. [29]. The efficacy of using VR for COVID-19 patients with CVA is further shown in the study done by Gao et al. [30].

The following factors made our technique unique: a) placement of the balls can be adjusted by the therapist according to the patient's assessment of a specific point on the clock face (from the perimeter to the center) before the start of the game, b) the assessment of the ROM in the shoulder joints and elbows are displayed in real-time on the screen and can be monitored at any time, c) the ROM of the shoulder and elbow joints are recorded at the end of the game for every patient, d) by comparing pre-assessment and post-assessment ROM and progression, a correct judgment of the patient's improvement is made, and e) the time in which patient spends at each stage of grasping, holding, and dropping the ball is recorded and used as a measure of Muscular Function & Fatigability.

IV. Conclusion

Finally, the reported case showed a good outcome in this patient with CVA likely related to COVID-19. The lack of adverse effects and high safety profile of this developed technique for such cases suggests that VR may improve therapeutic outcomes and prognosis patients. Further studies are required to attain definitive data on this topic.

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