

Case Report

Virtual Reality Rehabilitation for Optimizing Function Following Radial Nerve Injury: A Case Report

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Abstract: *Background:* Radial nerve injury can cause severe impairment due to paralysis of the wrist and finger extensors. Wrist drop is a hallmark feature of radial nerve injury. Various interventions are used for optimizing function. This case report uses virtual reality (PABLO tyro motion) to prove that such sensor-based rehabilitation can bring about better outcomes in current day clinical practice. Because radial nerve palsies improve over time with excellent prognosis, the current intervention used in the study was to facilitate and speed up the rehabilitation process due to decreased length of stay and time constraints of the subject staying long in the hospital. *Objective:* (1) To analyze the functional gain achieved from admission until discharge from hospital, thereby understanding the effect of virtual reality; (2) to understand the effectiveness of advanced technology such as virtual reality which can be used to facilitate function following nerve injuries. *Method:* We present a case of a 30-year old working male, who sustained radial nerve injury after a right humeral fracture, resulting from road traffic accident. A complete wrist drop was seen in the right hand, which was his dominant hand. This significantly affected his ability to independently perform activities of daily living (ADL) and engage in any other work-related activities. *Results:* Progressive recovery was seen following active rehabilitation, after an 8-week hospital stay. Improvements were seen in his abilities to perform ADL on the functional independence measure (FIM), improved muscle strength and active range of motion of the right hand, particularly wrist extensors, improved arm and hand function and decreased pain as measured by the outcome measures. *Conclusion:* Virtual reality can be used as an advanced treatment option for those with nerve injuries, even though there is spontaneous recovery over a period. This can be used to speed up the rehabilitation process to reduce length of stay and constraints in staying in the hospital.

Keywords: Wrist Drop, Radial Nerve Injury, Functional Independence Measure, PABLO Tyro Motion, Wrist Rehabilitation, Range of Motion, Muscle Power

1. Introduction

Wrist drop is the hallmark clinical feature of a radial nerve injury. It is a condition wherein the person cannot extend their wrist as it hangs flaccidly [1]. Radial nerve injury causes paralysis and weakness of the extensor group of muscles such as the wrist and finger extensors, resulting in functional impairment [2]. Upper limb motor impairments following a

neurological disorder, or a musculoskeletal trauma or insult is common and may cause functional limitations and dependence in selfcare tasks and poorer quality of life [3]. Various rehabilitation programs aim at promoting function, independence in tasks and they include constraint-induced movement therapy, electromyographic biofeedback, mental practice with motor imagery, repetitive task training, functional electrical stimulation, virtual reality and

Robot-Assisted Therapy (RT) [4-6]. Virtual reality-based therapy is an innovative approach and a more recent approach to neurological rehabilitation that uses intensive, repetitive, interactive, and individualized practice [7]. Previous reviews have suggested that virtual reality improves upper limb motor control and muscle strength [8-12]. There is growing evidence of rehabilitation programs using various types of robotics and virtual reality-enhanced devices to improve functional outcomes in patients with neurologic disorders such as stroke. But there is also evidence that such robotics and virtual reality is used and proven effective in orthopedic rehabilitation such as use of robotic assisted devices following traumatic lesions of the hand after surgery [13]. This suggests how task-oriented rehabilitation approach can also benefit patients with orthopedic disorders of the wrist and hand [14]. This led to the idea of using the PABLO Tyro motion, a virtually enhanced device. PABLO consists of objective assessments, monitoring and reporting system and a therapeutic software with many games adapted to clinical status [15]. Hence, this device was used in this case study to facilitate wrist extension, through assessment and therapy as used in other studies [13, 16].

2. Case Presentation

A 30- year old male suffered from polytrauma due to road traffic accident. It was a pedestrian hit by car scenario. He was a plumber by profession. He had multiple fractures which included fractures of the left anterior ribs 4th-7th, right humerus fracture, right tibial open fracture and other comorbidities like small bilateral pneumothorax, bilateral lung contusions. On August 21st, 2020, he had an open reduction and compression 4.5 plate fixation for the right humeral shaft wedge fracture and an intra-medullary nailing (T2 stryker) for right tibia shaft open fracture. Following the procedure, he noticed weakness in the right hand specifically in the right wrist as he was unable to move it. On initial assessment, the patient was conscious and alert. Cognition and speech were within normal limits. Sensation was intact. A complete flaccid wrist drop was seen on admission. His muscle weakness corresponded to MRC (Medical Research Council) grade 3 in the affected shoulder and elbow were grade 3 according to manual muscle testing system. The muscle power in the wrist extensors was grade 1 (flicker). He was hospitalized for 8 weeks at Hamad General Hospital, later shifted to Qatar Rehabilitation Institute and discharged from the hospital in October, 2020, after he was able perform self-care under close supervision/setup. Performance in the activities of daily living and functional assessments and functional status were measured every 2 weeks until discharge from hospital. Functional Independence Measure (FIM) to assess activities of daily living performance [17, 18]. Upper limb functioning was also measured using the Action Research Arm test (ARAT) [19]. The ability of the patient to perform certain upper extremity activities was measured using the Disabilities of Arm, Shoulder and Hand (DASH) [20, 21]. Patient-Rated Wrist Evaluation (PRWE) was used to measure wrist pain and disability in activities of daily living [22]. Muscle power of the upper extremity was evaluated using Manual muscle testing system according to Medical

Research Council (MRC) guidelines. The active range of motion was measured using Goniometer.

Functionally, the patient was maximally dependent in most of the self-care tasks due to difficulty in using the right hand in activities. He was under the orthopedic follow-up and was under all regular routine investigations. The multi-disciplinary team decided for an active rehabilitation program for 6 to 8 weeks. The goals set were to be independent in ADLs and ambulation for job reintegration. The daily living occupational therapy and virtual reality training were performed every day. The sessions included 1 hour/day for the virtual reality training, Functional electrical stimulation (FES) for 30 min/day in addition to conventional Occupational therapy was also given for 30 min- 40 min every day. Adequate rest breaks were given between activities, considering the patient's fatigue and therapy tolerance levels. The intensity of the virtual reality training was increased by adding more challenging levels, requiring more active range of motion, in all degrees of movements. The study purpose and methods were explained to the participant before his inclusion in the study, and he provided informed consent. The expected outcome of the study was to see an increase in various aspects such as the active range of motion, change in muscle power (mainly of the wrist extensors), functional status of the hand in performing self-care and functional tasks and functional gain in occupational performance and a decrease in pain and increased satisfaction overall. The study was reviewed and approved by the Medical Research Council. Written consent was obtained from the participant for his participation in the study.

3. Results

Table 1 shows a steady progress from 80 points at the time of admission, 96 points after 2 weeks, 102 points after 4 weeks and 111 points at the time of discharge. This showed a functional gain of 38.75% overall. The power in the wrist extensors were seen to improve from grade 1/5 (flicker) to grade 3/5 at the end of the rehabilitation program (table 2). Table 3 shows changes in AROM of the wrist extension (which was particularly noted) from 10 degrees to 55 degrees. A graphical representation of the improvements in FIM scores and active wrist extension (figure 1) and noted functional improvements in wrist extensors (figure 2) are seen.

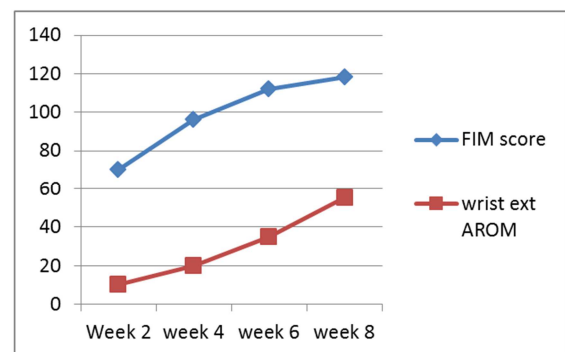


Figure 1. Graphical representation showing progress in FIM scores and wrist extension AROM.

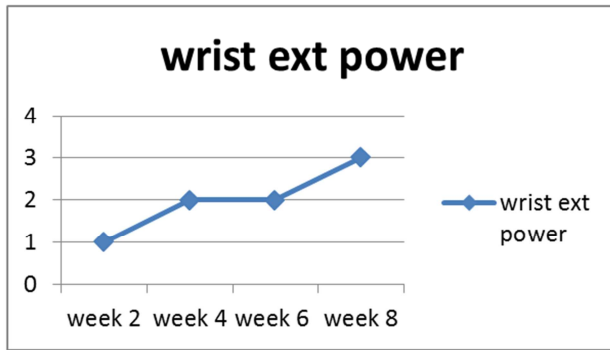


Figure 2. Graphical representation showing improvements in wrist extensors power (MRC).

Table 1. Changes in Functional Independence Measure scores.

	1st	2nd	3rd	4th	Δ%
Eating	4	4	5	5	
Grooming	4	4	5	5	
Bathing	2	4	4	5	
Upper body dressing	1	4	4	6	
Lower body dressing	1	3	4	5	
Toileting	3	3	4	6	
Bladder Management	5	7	7	7	
Bowel Management	5	7	7	7	
Transfers (bed, commode, tub)	4	5	5	6	
Walking	4	5	6	6	
Stairs	4	5	6	6	
Cognition	7	7	7	7	
Total points (score)	80	96	102	111	38.75%

$$\Delta\% = [(Posttest-Pretest) / Pretest] \times 100.$$

Table 2. Change in muscle power (according to Medical Research Council; Manual Muscle testing system).

	1 st	2 nd	3 rd	4 th
Sh. Flexors	2-/5	2-/5	3-/5	3+/5
Extensors	2-/5	2-/5	3-/5	3+/5
Abductors	2-/5	2-/5	3-/5	3+/5
Adductors	2-/5	2-/5	3-/5	3+/5
Ext. Rotators	2-/5	2-/5	3-/5	3+/5
Int. Rotators	2-/5	2-/5	3-/5	3+/5
ElbowFlex	3-/5	3-/5	3/5	3+/5
Extensors	3-/5	3-/5	3/5	3+/5
ForearmPron	1/5	2-/5	3-/5	3/5
Supinators	1/5	2-/5	3-/5	3/5
Wrist ext	1/5	2-/5	2-/5	3/5
Flexors	2-/5	2/5	3-/5	3/5
Hand	3+/5	3+/5	4/5	4/5

Table 3. Changes in AROM degrees (wrist).

	1 st	2 nd	3 rd	4 th
Wrist Ext/ Flexion	10/40	20/45	35/55	55/70
Radial/ Ulnar	5/10	5/12	10/20	15/30

4. Discussion

This case study demonstrates that 8 weeks of daily living occupational therapy and virtual reality training program can improve performance in the activities of daily living and muscular fitness in a patient recovering from radial nerve injury. Conventional Occupational Therapy and Functional electrical stimulation was also part of the therapy program.

Recovery from radial nerve injuries take a longer time than ulnar and median nerve injuries in accordance with neurological literature and with clinics- the flexion of the wrist and fingers recovered before extension [13]. Patients who worked with virtual reality training as in the use of PABLO tyro motion system for 30 minutes in addition to classical rehabilitation program, experienced better functional scores. The benefits of PABLO game therapy showed improvement not only of locomotor values (ROM, strength, prehension), but also of attention, motivation, dexterity, based on audio-visual and haptic feedback that can help the patient in the early recovery process, according to previous studies [13, 23]. In the present study, PABLO therapy was used for 1hr/day and had shown improvements in function from the time of admission until discharge. As a result, functional gain was seen with increase in the FIM scores. A significant functional gain of 38.75% was achieved, as shown in table 1. This was gradually achieved over the course of rehabilitation from admission to discharge. This suggests that the rehabilitation program was effective in bringing about greater functional independence and ability to perform work-related activities.

In addition, the present study found that in terms of muscular fitness, increase in muscle power were seen in shoulder, elbow, forearm, wrist and hand muscle groups. The muscle power in the wrist extensors on admission was just a flicker. Following virtual reality training, the power in the wrist extensors were seen to improve to grade 3/5 at the end of the rehabilitation program, which was 6 weeks from admission (table 2). Hence, virtual reality training has shown to have a significant effect and change in function in areas of wrist rehabilitation, particularly following radial nerve injury. Notable progress was also seen in active range of motions of the wrist extension in the affected extremity. According to table 3, the active range of motion at the time of admission was 10 degrees of wrist extension. With subsequent PABLO and rehabilitation therapy programs, the active ROM improved to 55 degrees of wrist extension, which was a remarkable change. The patient also reported decrease in pain over the course of therapy, based on the numeric pain rating scale. This change in muscle power and range of motion had a direct impact on the patient's functional status in terms of performing self-care, and increased levels of satisfaction and motivation to use the virtually enhanced device and therapy programs. This is supported by previous studies which analyzed the effects of VR intervention on upper limb motor function. It was found that the focus of majority of these studies were on improving the upper limb range of motion [24], upper limb strength/power and functional performance in activities [25].

Positive changes in scores were also reported on the ARAT scale, which measured hand functions. He was able to functionally use the right hand in picking and manipulating items. With regards to DASH scores and PRWE, the patient reported that he experienced lesser extent of pain as when compared to the initial stages. This is supported by the results of one of the studies [13], which also mentioned that the use of such game modules with the PABLO showed better evolution of the DASH score and significant decrease in pain.

5. Conclusion

In conclusion, the present study suggests that the combined daily living occupational therapy and PABLO therapy was effective in improving performance in activities of daily living and muscular fitness and functional status. The present study can also strongly suggest that the PABLO device can be used as an objective testing measure that can be very useful in clinical assessment and treatment of patients with post-traumatic hand. Since this was a case report of a patient with radial nerve injury, further studies on a large scale is required to establish a strong evidence that virtual reality alone can be an effective therapy program in wrist and hand rehabilitation. Considering the spontaneous recovery of such nerve injuries, it is imperative to use such treatment interventions to facilitate faster recovery to optimal function and to promote return to home.

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