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Development of a Virtual Reality System for Early Mobilization of Critically Ill Patients

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Abstract

More and more researchers have recommended critically ill patients to start mobilization as early as possible. However, the clinical utilization rate of early mobilization remains low for patients in the intensive care units (ICU) because of various factors. In order to promote the rehabilitation of critically ill patients, a multidisciplinary research team, including academic researchers, ICU head nurses, respiratory therapists, and a software engineer, has developed a virtual reality system for early mobilization in ICU. This system has four main features-the diverse forms of mobilization based on muscle strength, the integration of exercise and cognitive training, the visualization of the mobilization process and the record of the trajectory during mobilization exercises. This paper presents and discusses the development process of this system.

Keywords:

Critical illness, early mobilization, virtual reality

Introduction

With the advancement of medical technology, researchers concern not only the increase in survival rate with technology, but also the quality of rehabilitation of critically ill patients[1]. Traditionally, rehabilitation begins after patients are discharged from ICU, which could be too late for the recovery of physical and cognitive functions, causing a majority of ICU patients to lose their ability of independent living and the quality of life[2]. In recent years, researchers have suggested that early mobilization for critically ill patients during treatment in ICU can circumvent many complications, reduce the hospitalization length and improve their quality of life[3]. However, the current implementation of early mobilization in ICU is not well administered. The main reasons are due to the shortage of medical staff, equipment and other resources, and more importantly, patient's unwillingness to exercise. Therefore, it is necessary to explore methods to improve the motivation and compliance of critically ill patients towards early mobilization. Recently, many researchers have used information technology to assist patients in the rehabilitation process, where virtual reality technology, as novel information technology, has the potential to meet the needs of promoting early mobilization concerned with this research. Hence, our team has developed a virtual reality system to assist ICU patients and record their progress in early mobilization. The system is presented and discussed in this paper.

Methods

A multidisciplinary research team including academic researchers, ICU nurses, respiratory therapists, and a software engineer was set up. The team had been involved in designing early mobilization strategies for ICU. ICU nurses and respiratory therapists have rich experience in critical care and early mobilization.

Stage 1: Alpha Version of the System

After reviewing literatures on ICU early mobilization and making reference to clinical experience, our research team came to the conclusion that early mobilization of ICU patients would be administered based on the muscle strength of their upper and lower extremities as measured by the MRC Muscle Scale; and that mobilization would be performed step by step. Then, the functions of the system were determined, which included diverse forms of mobilization based on muscle strength, integrating exercise and cognitive training, the visualization of the mobilization process and the record of the trajectories during mobilization exercises.

Stage 2: Beta Version of the System

The alpha version of the system was refined based on the result of stage 1. It was re-programmed to increase the ease of use by providing a user-friendly interface. The fidelity of the system was also improved by modifying the algorithms and parameters of the computer program so as to better capture the motion of the lower limbs.

Results

The virtual reality early mobilization system for critically ill patients has been developed after several rounds of discussion and modification. Before using this system, the medical staff is required to assess the patient's basic vital sign and muscle strength. In the first page of the system, medical staff should fill in patients' name, age, gender and muscle strength (Figure 1). Based on the inputs, they are provided with suggestions on the form of early mobilization, the dosage, and intensity that are suitable for the patients. The four basic functions of the system are described as follows.

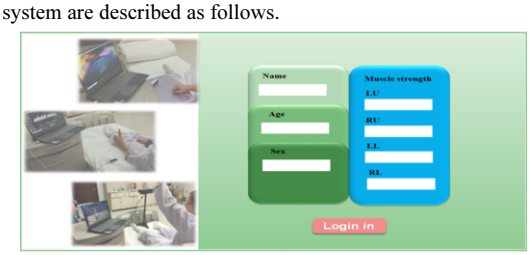

Figure 1– First page of the system

Function 1: Diverse forms of mobilization based on MRC

This function is to identify the best form of early mobilization for patients according to their muscle strength, which is depicted in Figure 2. For example, patients with an MRC Score

of 2 for their upper extremity muscle strength need to complete plane movement, fisting activity, and wrist flexion.

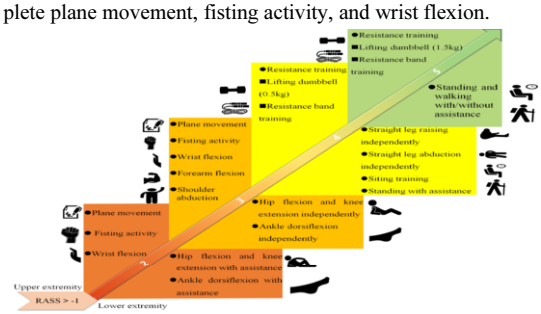

Figure 2–Different mobilization strategies

Function 2: Integration of exercise and cognitive training

With this system, every patient is suggested to receive various physical and cognitive training. For instance, patients with an MRC Score of 2 for upper extremity muscle strength need to complete plane movement integrated with cognitive training, in which patients are guided to write or draw using a visual sensing device. When the MRC Score for the upper limb is greater than 3, a variety of exercise games are recommended for the patients to choose. The games require patients to make a decision and stimulate their thinking while motivating them to exercise more and making it an enjoyable process as a whole.

Function 3: Visualization of the mobilization process

After adjusting the devices and computer, data about the movement of the critically ill patients can be transmitted to a laptop, where all the processes of the mobilization can be visualized. In some games, the virtual person appearing on the screen could follow the actions of the patient. Standard exercise indicators are displayed on the screen to assist patients to judge by themselves whether their movements are correctly performed. Furthermore, in the games of playing piano, jumping frog and others, patients can gradually increase the intensity of exercise and target at the higher game score, which is helpful to increase the interest and motivation of early mobilization. By adding algorithms into the program, the ability of patients in meeting the criteria of mobilization can be judged and the frequency of exercise can be recorded.

Function 4: Record of trajectory during exercises

The trajectory during mobilization exercises can be recorded by the system by capturing the patient's movement with a camera. In the later stage, the trajectories of daily mobilization exercises can be compared, which can fully reflect the rehabilitation trend of the patient.

Discussion

This is the first study to develop a virtual reality system on early mobilization for critically ill patients. It is well known that there are many barriers in implementing early mobilization for patients in ICU, such as patient-associated factors, structural issues, process factors, and cultural factors. Among these factors, patient's willingness is the most important factor that is difficult to deal with. According to clinical investigation, patients with critical illness often show frailty, indifference, and melancholy, which are partly due to the physical diseases and the psychological status of the patients. Medical staff should recognize the true state of patients, and then remove the discomfort from patients, and actively encourage them to exercise as early as possible. However, ICU medical staff already have a heavy workload. It is difficult to carry out early mobilization for the patients. The development of this system can help improve compliance of critically ill patients on early mobilization. The usual care in ICU could make patients feel boring, making it difficult to adhere to and achieve the effect of rehabilitation. The proposed system utilizes virtual reality technology to enable patients to gain interesting experience with various forms of exercise, making them more willing to participate actively in rehabilitation therapy. This system can also reduce the workload and pressure on the medical staff.

One of the innovations of the system is the integration of exercise and cognitive training. Although some studies tried to combine early mobilization and cognitive training, the two interventions were separate and patients have to receive them independently. In addition, exercise games are goal-oriented, giving patients a good sense of achievement when they achieve their goals. More importantly, the usage of the system does not require patients to wear or carry any objects. Patients can use their fingers as a pen to interact with computer programs, thus making them feel more natural when doing the exercises.

Another innovation of the system is to record the trajectory of exercises for critically ill patients. The dynamic changes of patients' movement are often difficult to capture and describe clearly. This system allows for the visualization of patients' movement during the whole process, which can also be recorded for analysis. With this function, the patient can understand their progress and the effect of rehabilitation more intuitively, which is beneficial to enhance their belief and confidence in early mobilization. For medical staff, the system provides more detailed data and record about the progress of recovery.

A limitation of this study is that it targets only at patients who are awake and with moderate muscle strength, For patients in coma or with lower MCR Score, medical staff is still required to perform passive or assistive exercise intervention for the patients. We will conduct research on this aspect in the pursuit of research breakthroughs.

Conclusions

This study described the development process of a virtual reality system by a multidisciplinary research team for early mobilization in ICU. The system is developed with novel design concepts and practical features. It can be applied to promote early mobilization of critically ill patients. This system motivates patients to exercise with engaging designs and records the trajectory of mobilization and rehabilitation. A further improved version of the system will be developed after addressing the comments from clinical experts and patients. The system has the potential to enhance the rehabilitation and the quality of life for ICU patients. It is expected to play an important role in clinical applications.

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