Design of Upper Limb Patient Simulator

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Abstract

Spasticity is one of the muscle diseases in upper limb that is often seen in the patients of stroke and shoulder paralyzed. The disease occurs when the patients central nerve is damaged, leading the patients having resistance in the joint when they try to move it. In the area of orthopedics and rehabilitation, it has become essential to study the characteristics of human joint and muscle diseases. In this paper, an experiment to measure the characteristics of the disease was conducted and the data is used to reproduce the symptoms of spasticity in an upper limb patient simulator. The developed patient simulator is built with the joint and three bones of human arm: humerus, radius and ulna and is evaluated in term of reproducibility of the spasticity stiffness by two experiences physiotherapist.

Keywords: Patient Simulator, Rehabilitation, Upper Limb Disorder, Spasticity

1. Introduction

Spasticity is a muscle control disorder caused by an imbalance of signals from the central nervous system which is the brain and the spinal cord to the muscles. It is a disease with the symptom of inability in moving the body joint voluntarily. The muscle or a group of muscles are not able to work properly due to stroke, cerebral palsy or accidents leading to a condition we called spasticity. Although it has limitation, Ashworth Scale is the primary evaluation method to measure spasticity especially for upper limb [1]. There are several quantification methods under study [2]. Stroke, one of the causes of spasticity, is a major concern in worldwide [3] and is one of the priority areas for the British National Health Service (NHS) [4]. Statistics from National Stroke Association of Malaysia (NASAM) shows that approximately 40,000 Malaysian people are disabled by stroke every year. Stroke is also the leading cause of severe disability in Malaysia which is similar to other developing and developed countries. The number of stroke patients admitted to the Malaysian Ministry of Health (MOH) hospitals has been increasing (MOH, 2006) from 13,868 in 2000 to 16,805 in 2004 (National Institutes of Health, Malaysia [NIHM], 2006).

2. Problem Statement

Patients suffer from the spasticity diseases need to go through physiotherapy session in order to return to their normal social life. Therefore it is crucial for physiotherapist to assist the spasticity patients, however at the same time the physiotherapists’ trainees obtain their skills through clinical practical training. Clinical training will involve cooperation of patients for them
to gain experiences. Unfortunately, there are not enough opportunities to gain experiences and the training will also risking the patients. Normally to avoid risk to the patients, the trainees practices with their colleagues through patient role play, who try to imitate the actual symptoms such as movement stiffness where they are not able to fully imitate stiff muscles.

In the field of rehabilitation, there exist rehabilitation robots to help the patients of upper limb disorder such as Tailwind and Myomo Inc. These devices help the patients to resume their normal life but it still need the guidance and final evaluation of the progress from fully trained physiotherapist. Therefore it is important to develop an upper limb patient simulator for the physiotherapist trainee to gain experiences without risking the patients.

3. Mechanism of Patient Simulator

3.1 Spasticity Model

The fundamental of the human upper limb anatomy consists of humerus, radius and ulna. Humerus is the upper arm bone that joint with radius, the bone on thumb side of lower arm and the ulna, the medial bone of forearm [5]. Figure 1 (left) shows the articulation of the elbow and forearm complexity. The patient simulator is trying to imitate the elbow and forearm complexity by reproduce the bones and the pronation and supination. Pronation is the rotation of radius around the fixed humerus as shown in figure 1 (right). The supination is the opposite movement of pronation [6].

There are a number of human elbow model that have been developed such as spastic elbow of a child [6], of an adult [7], and prototype of normal human elbow joint [8]. Spasticity patient simulator need to imitate the joint of human elbow and must be able to reproduce the symptoms of spasticity. We have developed a system simulating human arm from fingers to the shoulder region build with the humerus, radius and ulna bones.

Apart from reproducing the joints and bones, the patient simulator must also be able to reproduce the symptoms of spasticity. We have measured the properties of the spasticity symptoms with the help of two physiotherapists, one is playing a role of a patient and another one is performing the rehabilitation as in Figure 2 (left). Load cell range 0-100 [kg] (μTas MT-1 Anima Corp.) was attached to the physiotherapist to measure the force exerted by the patient. The sequence of the elbow joint angle was analyzed with FrameDIAS. The relationship of moment around elbow axis and the angle shows in Figure 2 (right) is later used in reproducing the spasticity symptoms.

3.2 Device Design

The upper limb patient simulator is developed with one degree of freedom imitating human arm with humerus, radius and ulna (Figure 3 (right)). The patient simulator represents the left hand. The radius acted as a cam follower connected to the humerus with an oval shape cam to reproduce the pronation and supination during rehabilitation. In addition, a spherical bearing is used to imitate the angle of radius. Figure 3 (left-below), shows the 30 degree complete forearm rotation. In
average, daily activities require around 100 degrees forearm rotation – 50 degrees of pronation and 50 degrees of supination. In rehabilitation, persons who lack of 30 degrees of complete forearm rotation are still capable of performing daily activities [6]. An imitation skin is used to cover the device for a better visual appearance.

The active and passive force of spasticity symptoms are displayed by MR brake and DC servomotor respectively. The symptoms are reproducing by controlling the reaction force from physiotherapist passively from the result shown in Figure 2 (right). Magneto-Rheological (MR) fluid in the MR brake acts as a resistance against the rotation of the elbow joint. MR fluid change its viscosity property based on the input signal and reproduce stiffness of the elbow joint.

![Image](image_url)

Fig. 2 (left) Experiment of Simulated Spasticity; (right) Moment and Angle of Motion – Simulated Spasticity

![Image](image_url)

Fig. 3 (upper left) Upper Limb Patient Simulator; (below left) Enlarged view of elbow joint (right) Radius and ulna bones of the patient simulator
3.3 System Evaluation

Evaluation of the upper limb patient simulator was conducted with the help of two experienced physiotherapists. Strain gauge is located at the middle forearm to measure the force impulse by the physiotherapist and a rotary encoder measures the angle of the elbow. Moment around elbow joint and force exerted by the strain gauge was measured. System configuration is shown in Figure 3 (upper left). Comparing evaluation result from Figure 2 (left) and Figure 4, the upper limb patient simulator is able to generate almost the similar symptoms of spasticity. The elbow joint is giving the stiffness of spasticity based on the input data to the system.

![Figure 4 Evaluation of the spasticity Symptoms](image)

4. Conclusion

The patient simulator which emulates human upper limb forearm of spasticity patient to assist the physiotherapist trainee is developed. The developed upper limb patient simulator is replicated to imitate the joints and bones of the human arm anatomy. The simulator obtained good feedback from the physiotherapists as it is able to reproduce the resistance and elbow stiffness clearly and with almost constant resistance. With the first step of replicates the human arm anatomy and its system configuration, we will be able to reproduce other symptoms as well such as Cogwheel Rigidity and Lead-pipe Rigidity Symptoms.

However, the viscous elasticity of the biceps brachii muscle and the tendon expand during rehabilitation which is importance for the physiotherapists are still in the development stage. Further research will focus on reproducing other symptoms and replication of biceps brachii muscle to increase usability and reality of the upper limb patient simulator.
References


