Rehabilitation Robotics –
Innovations in Tertiary Prevention of Stroke Patients

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ABSTRACT
Stroke is one of the major causes of human morbidity and mortality. It ranked as the sixth leading cause of disability-adjusted years in 1990. The geriatric population is increasing in India and with this the burden of stroke and the patients needing specific rehabilitation are rapidly multiplying. Rehabilitation robotics presents the hope of putting the patients back in the society and is becoming a necessity for the low resource country like India. The area is under immense research with researchers trying to classify different robots. This paper presents the classification of Rehabilitation robots, which can increase the awareness in society on one hand and for experts who can tailor the use of robotics for specific problems in stroke patients.

KEYWORDS
Stroke, Rehabilitation, Robotics, Classification

INTRODUCTION
Stroke is one of the major causes of human morbidity and mortality. It is ranked as the sixth leading cause of DALY (disability-adjusted life years), in 1990 and is projected to rank fourth by the year 2020. One DALY is one of the lost years of healthy life. The survivors face the dreaded consequence of being handicapped depending on the severity of stroke. The mental trauma of being incapable of living normal life is several times more than of physical disability. With the patients, their families undergo the long-term stress of care giving and budgeting. World Health Organization defined stroke as “rapidly developed clinical signs of focal (or global) disturbance of cerebral function; lasting more than 24 hrs or leading to death, with no apparent cause other than vascular origin”[2]. It was estimated that stroke represented 1.2% of all deaths in the country when all ages were included. Although the prevalence of stroke appears to be relatively less in India than in developed countries, it is likely to amplify proportionally with the increase in life expectancy [1]. While mortality due to stroke has steadily declined over the years with better care, stroke remains the foremost cause of long-term physical and mental disability in adults, in both developed and developing countries and the most familiar reason patients are referred for rehabilitation. Rehabilitation has been defined as “the combined and coordinated use of medical, social, educational and vocational measures for training and retraining the individual to the highest possible level of functional ability” [3]. The main objective of rehabilitation is to optimize functional recovery. It includes all measures aimed at reducing the impact of disabling and handicapping conditions and at enabling the disabled and handicapped to achieve social integration. [4] Traditionally, this is usually achieved through highlighting on the reduction of disability and not impairment. Accordingly, if a stroke patient has difficulty caring for himself because of weakness of the affected arm, the stress will be on teaching him to compensate using the non-affected arm rather than spending time strengthening and reeducating the affected arm. However, this conventional stroke rehabilitation runs the risk of encouraging disuse in the affected limb, which may affect long-term recovery.

VALIDATION OF USING ROBOTS IN TERTIARY PREVENTION OF STROKE PATIENTS
Advances in neuro-imaging techniques such as Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET) and Transcranial Magnetic Stimulation (TMS), in addition to animal studies on neurological injury, have helped further our understanding of how the brain recovers after an insult such as a stroke. We now know that the adult brain is capable of reorganizing itself after suffering a stroke. This process of change and reorganization is referred to as plasticity [5]. The process of cerebral reorganization is activity or use-dependent and can be potentially manipulated. Furthermore, it is now known that even in the chronic stages of a stroke, the brain is still “plastic” and can reorganize in response to appropriate stimulus [5]. These findings have opened a new dimension for research in the field of neuro-rehabilitation apart from physical rehabilitation.
The rate of recovery greatly depends on the amount of focused training, along with stroke severity and cognitive availability [6]. However, since such focused rehabilitation requires supervision of trained professionals, lack of resources in a developing country like India, limits the amount of time available for supervised rehabilitation. This problem can be subjugated by the use of interactive robots.

Over the last few years, there has been considerable research looking at the role of interactive robotic devices in rehabilitation, what is known as Rehabilitation Robotics.

HISTORICAL PERSPECTIVE
Built in the early 1960’s, the CASE manipulator was the first referenced rehabilitation robot. [7]. It was a powered orthosis to move the patient’s affected arm. Another similar orthosis, the Rancho Los Amigos manipulator was a little advanced project.

The concept of rehabilitation robotics gained momentum and specific researches started in mid 1970’s. A workstation based rehabilitation system designed by Roester [8], in Heidelberg, West Germany was one of the earliest projects.

Another robotic system in 1974 was that of Seamone and Schmeisser at the Johns Hopkins University. It was more advanced and could be manipulated by the arm using preprogrammed commands.

The Sparticus robot [9] in France was a high quality manipulator, which inspired to the Manus Project in Holland and the Master project in France. In early 1980’s, the development of DeVAR (Desktop Vocational Assistive Robot) workstations [10], were aimed at providing a vocational environment to the paralyzed stroke patient

One of the pioneer researches in giving the concept of powered feeding devices as early as 1987 was the Masters Research Project at Keele University [11].

In the mid-1990s, proof of concept studies began with MIT-Manus to determine whether intensive, robotic therapy was effective in reducing motor impairment after stroke [12].

As given in [13], stroke patients with impaired hand use reported improved ability to grasp and release objects after therapy sessions using the Hand-Wrist Assisting Robotic Device (HOWARD).

The last and current decades are the spectators of rapid and advanced researches in the field of rehabilitation robotics for the benefit of patients suffering from stroke. Citing all the important researches are out of scope of this paper.

CLASSIFICATION SCHEMES AND RELATED STUDIES
An important paper [14], defines the research area of socially assistive robotics, focusing on assisting people through social interaction. The author also differentiates between robots that provide assistance to people through physical contact (called Contact Assistive Robotics), and robots that entertain through social interaction (called Social Interactive Robotics). Another paper [15] presents new human-centered robotic approaches applied to the rehabilitation of gait and upper-extremity functions in patients with movement disorders. The author describes that "patient-cooperative" strategies can take into account the patient's intention and efforts rather than imposing any predefined movement, and hypothesizes that such human-centered robotic approaches can improve the therapeutic outcome compared to classical rehabilitation strategies.

Therefore, the different categories of Rehabilitation Robotics are presented as follows:

CATEGORIZATION SCHEME 1
Contact assistive robotics
-robots that provide assistance to people through physical contact
Socially assistive robotics
-robots for assisting people through social interaction.
Social interactive robotics
-robots that entertain through social interaction.

CATEGORIZATION SCHEME 2
Classical rehabilitation strategies
-Here predefined movement may be imposed on the patient by the robot.
Patient-cooperative strategies
-These take into account the patient's intention and efforts.

SCHEME 3 – THE SUGGESTED CATEGORIZATION
In this suggested categorization scheme, the rehabilitation robotics is classified as the following:
Cardiopulmonary Rehabilitation Robots
- like the Concept of Modified Delta Parallel Robot [16]
- Robot assisted gait (Treadmill Training) with a feedback system for the oxygen uptake and performance in patients
- Robots in combination with hyperbaric oxygen delivery system.

NeuroRehabilitation Robots
Robot assisted gait-training systems, exercising systems for nerve regeneration.

Musculoskeletal Rehabilitation Robots
a. Mobility Robots
   i. Locomotion Robots
      1. All terrain chairs, wheeled/legged systems
   ii. Navigation Robots
      1. Intelligent wheel chairs
      2. Intelligent homes, buildings
b. Manipulative Robots
   i. Upper Limb Manipulation
      1. Prosthetic arms
      2. Powered feeders
   ii. Lower Limb Manipulation
      1. Different orthosis having pressure sensors
      2. Gait control devices
CONCLUSION
Rehabilitation robotics presents the hope of putting the patients back in the society. This paper has presented different categorization schemes of Rehabilitation Robotics and has also given a suggested classification that will be useful for making new applications for Stroke Patients.

FUTURE SCOPE
Rehabilitation robotics is just beginning to make serious inroads in the world of physical therapy, but already the results are miraculous in many cases.

REFERENCES
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