Rehabilitation Robotics: How Old is Too Old?

H. I. Krebs, B. T. Volpe, N. Hogan

***Abstract*—Different epidemiological studies appear to support the view that age correlates well with final ADL competency but not with potential changes observed from admission to discharge of a rehabilitation program following stroke. There are fewer studies on whether age is a limiting factor of neurological recovery. Here we examined in one-hundred and eleven stroke survivors (range of 19 to 81 years old), who volunteered for our studies on robot-mediated therapy, if age correlated well with observed neurological improvement. Results suggest that age is not a limiting factor on neurological recovery (R=0.016), adding to previous retrospective studies on ADL changes, and demonstrates that there is no rationale in limiting access to rehabilitation care to the elderly.**

I. Introduction

THE last 75 years of rehabilitation therapy practice and research have provided very few actual answers to ameliorate and maximize outcomes of stroke survivors. Rehabilitation practice remains an art rather than a science. To change this landscape, we have engaged in randomized control trials using robots, which can deliver a variety of well-controlled reproducible therapy and help us determine these needed answers. In previous research, we have shown robotic therapy to be effective in reducing motor impairments of the hemiparetic upper limb in persons who are in the acute phase of stroke recovery [1]-[4]. More recently, we have shown that the robotic therapy is also effective in reducing motor impairments of persons with chronic stroke [5]-[7]. Specifically, robot mediated therapy led to significantly improved motor coordination and muscle strength of the exercised shoulder and elbow muscles, as measured by clinical evaluations.

Stroke recovery is a multifaceted process and practitioners have hypothesized a multitude of variables that influence outcome. Yet little is known of the independence, actual impact, and interaction of these variables on outcomes. Here in this paper, we review and examine the role of patient age on the ability to recover.

In an influential paper, Nakayama and colleagues summarized the results in five-hundred and fifteen (515) consecutives stroke patients enrolled in the Copenhagen Stroke Study [8]-[9]. They determined that patients' age was strongly correlated with activities of daily living (ADL) but not correlated with neurological improvement or speed of recovery. Bagg and colleagues conducted a prospective study in Canada including all inpatients admitted to a rehabilitation program during 6 years. He focused exclusively in functional ADL competency and obtained a similar result, which was that age correlated well with ADL levels but not with change in ADL competency registered during rehabilitation [10]. Similarly, Luk and colleagues studied a retrospective cohort of Chinese stroke inpatients admitted to a neuro-rehabilitation ward in Hong Kong from January 2000 and December 2003 and arrived at the same conclusion that, while age correlated well with final ADL competence, it did not correlate with change from admission to discharge [11]. Finally, in Italy, Fiorelli and colleagues determined in three-hundred (300) consecutive stroke patients admitted to eleven primary care institutions that age correlated well with final ADL [12]. The consensus of these different studies in distinct countries and environments is that age correlates with final ADL competencies, but not with the potential for ADL recovery after stroke. It also appears that age does not correlate with neurological improvement and impairment reduction [8]-[9]. In this paper, we examine if aging limits the potential for neurological recovery following a stroke.

II. Methods

A. Subjects

We enrolled one-hundred and eleven (111) community dwelling volunteers. Inclusion criteria were: 1) diagnosis of a single, unilateral stroke at least 6 months prior to enrollment verified by brain imaging; 2) sufficient cognitive and language abilities to understand and follow instructions (Mini-Mental Status Score of 22 and higher or interview for aphasic subjects); and 3) stroke-related impairments in muscle strength of the affected shoulder and elbow between grades ≥1/5 and ≤3/5 on the Motor Power scale (MP) [13]-[14] (neither hemiplegic nor fully recovered motor function in the muscles of the shoulder and elbow). Subjects were excluded from the study if they had a fixed contraction deformity in the affected limb or if they demonstrated improvement over three measurements made during the four-week observation period prior to treatment. None of the subjects were engaged in conventional occupational or physical therapy programs nor did they receive pharmacological management of spasticity and tone (i.e., Botox) during the experimental trial. All subjects volunteered for the study and gave their informed consent. The experimental protocol was approved by the Committee on the Use of Human Experimental Subjects of the Massachusetts Institute of Technology.

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B. *Robot-Mediated Therapy*

We employed the MIT-MANUS and its commercial version InMotion2 (Interactive Motion Technologies, Inc., Cambridge, MA) to deliver therapy in this study. MIT-MANUS is a robot intended for promoting neurological recovery and designed at the Massachusetts Institute of Technology [15].

C. *Experimental Protocol*

All subjects participated in an 18-session robotic treatment protocol. Trials commenced after the baseline assessments on the F-M [16]-[17] and MP [14] showed that motor impairments were stable across three evaluation sessions spaced two weeks apart.

During each therapy session, subjects were directed to make a number of point-to-point movements, ending as near as possible to the target location, while sitting in a chair. The torso was restrained by a 5-point seatbelt to minimize torso movements, the elbow was supported by a low-friction pad, and the forearm and hand were supported by a specially-made arm trough that attached to the robot handle. During these sessions the robot was powered. If the subject was unable to move or hit the target, the robot assisted his/her hand toward the targets as needed [18]-[19]. A center target and eight targets equally spaced around a circle were displayed on a monitor, and visual feedback regarding the current position of the robot's endpoint (subject's hand position) was provided. The center of the workspace was located in front of the subject at the body midline with the shoulder elevation at 45^{o} and the elbow slightly flexed. Subjects moved from the center to each target and back, starting at "North" and proceeding clockwise. Each target was 14 cm from the center. Each therapy session lasted for 1 hour.

D. *Evaluation*

All subjects went through clinical and robot-based evaluations at the admission, mid-point (9th session), and the end of the treatment protocol. During the clinical evaluations, subjects' recovery was assessed via clinical scales. In this study only the results of the F-M scale are employed.

III. Results

Patients age ranged from 19 to 81 years old (mean 59.9 y.o. and sem 1.2 y.o). Results for this cohort of stroke survivors suggested that age was not a limiting factor. As shown in Fig 1, the correlation between age and changes in the Fugl-Meyer Assessment (neurological scale) for this cohort of one-hundred and eleven stroke survivors was actually very low (R=0.016).

IV. Discussion and Conclusion

The consensus of different epidemiological studies in distinct continents and health delivery system is that age correlates with final ADL competencies, but not with the neurological improvement and impairment reduction following stroke. These retrospective studies occurred in diverse areas including Denmark and Italy (Europe), Canada (North America), and Hong Kong (Asia). That the ADL competencies correlated well with stroke survivor age, particularly for the age group over 80 y.o. is not totally surprising and it might represent typical competency decline with aging. On the other hand, neither these retrospective studies nor our study were able to demonstrate a relationship between the stroke survivor age and his/her ability to recover. Hence, therapy should not be rationed based on age.

As we continue our studies, we will continue to monitor our patients' age to determine if this conclusion needs to be revised as we recruit older subjects.

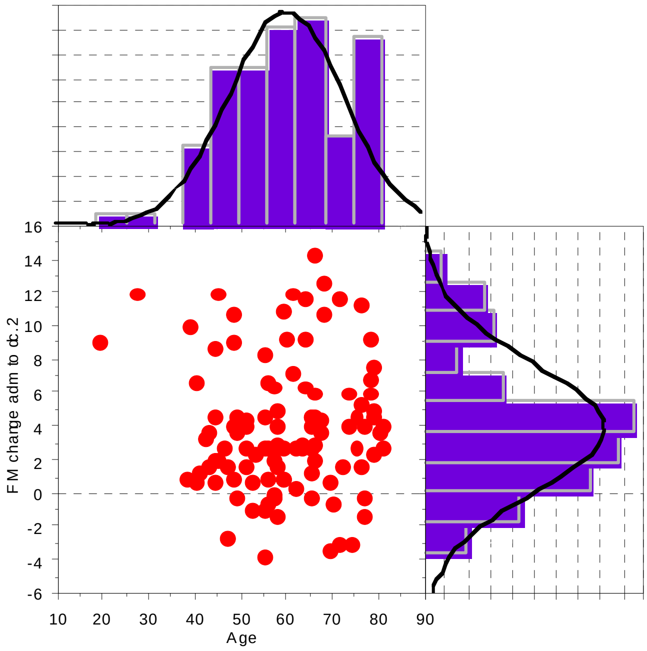

Fig.1. Age and Recovery in Chronic Stroke. The figure shows the distribution of age for the 111 community dwelling stroke survivors (19 to 81 y.o.) and the change in the Fugl-Meyer from enrollment to completion of the protocol. Volunteers' age and the neurological improvement (Fugl-Meyer) were not correlated.

Acknowledgment and Disclosures

H I Krebs and N Hogan are co-inventors of the MIT-held patent for the robotic device used in this work and hold equity positions in Interactive Motion Technologies, Inc., Cambridge, MA, USA, a company that manufactures this type of technology under license to MIT.

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