Effects of different robot-mediated therapies on the upper limb of elderly chronic hemiparetic subjects

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Abstract—**The aim of study is to compare two different robot-mediated therapies and to demonstrate their effectiveness in elderly chronic hemiparetic patients.**
Two different robot-mediated therapies, consisting of goal-directed, planar reaching tasks, were provided 3 times a week, for 6 weeks. For this purpose an innovative pattern of reaching exercises, named "fan-like" scenario, was also implemented. Eighteen patients, randomly assigned to two homogeneous group, were recruited in the study. The items for the shoulder and elbow of Motor Status Score and the Modified Ashworth Scale. Statistically significant improvements before and after treatment were found in both groups.
The results confirm that a robot-mediated therapy contributes to the decrease of the upper limb's motor impairment in elderly chronic neurological injury, reducing the shoulder pain too. Two questionnaires about the patient's acceptance of the robotic therapy show also a very high degree of satisfaction.
The implementation of different scenarios for robot-mediate therapies can contribute to optimize and personalize treatment protocols according to the specific motor impairment and the expected results.

I. Introduction

EPIDEMIOLOGICAL studies have shown that the average age of patients affected by stroke is 70 years in men and 75 years in women [1]. Most stroke survivors regain independent ambulation, but many of them fail to recover the functional use of the upper limb even after a prolonged rehabilitative treatment: these functional limitations are responsible for the reduction in the quality of life [2]. Recent studies have demonstrated that improvements in motor abilities induced by the therapy may even occur in chronically impaired paretic upper limbs more than 6 to 12 months post-stroke [3] by performing high-intensity and task-specific therapeutic interventions consisting of active and highly repetitive movements [4][5].

Recently developed robotic devices for rehabilitation can be very useful for providing a safe, highly accurate, intensive and prolonged motor therapy to patients with upper limb motor impairment [6]. The paper presents an innovative scenario for an upper limb robotic therapy, aimed at maintaining and increasing the movements involving the extension of the arm, particularly at the elbow level, contrasting the pathological flexor pattern. A robot-mediated therapy with this kind of scenario has been provided to elderly people in order to verify its effectiveness.

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II. Methods

A. Subjects

Eighteen hemiparetic subjects, aged 61-77 (mean age 66.17 ± 4.82), ten men and eight women, all right handed was recruited for the robotic therapy. All of them had suffered the acute event at least one year before the beginning of the study. Flaccid hemiparesis was an exclusion criteria (Chedoke-McMaster Stroke Assessment Scale score = 1), so only patient having a spastic upper limbs were included in the present study. Subjects were randomly assigned either to Group A or Group B.

Group A composed of nine subjects, aged 61-77 (mean age 65.44 ± 5.13), six men and three women, was recruited for the robotic therapy already used in previous studies. Six of nine were resulted in right hemiparesis, three in left hemiparesis.

Figure 1. Subject posture and the experimental apparatus at the clinical site

Group B composed of nine hemiparetic subjects, aged 61-75 (mean age 66.89 ± 4.67), four men and five women, were recruited for the robotic therapy using an innovative scenario. Six of nine were resulted in right hemiparesis, three in left hemiparesis.

The experimental protocol was approved by the local ethical committee. Each subject signed a consent form.

B. Apparatus

Robot-mediated therapy was delivered using the MIT-MANUS, a robot designed for clinical neurological application [7]. It can move, guide and perturb the movement of a patient's upper limb, recording variables such as the position, velocity and applied forces.
The MIT-MANUS (Figure 1) allows subjects to execute reaching movements in the horizontal plane. During the movements the device can assist the subject's movements or resist to them. It was designed for a safe, stable, and compliant interaction with the subject, throughout the training paradigm. It is a modular system, consisting of a planar module, a wrist module and a linear module.
The planar module was used during the present study: it provides two translational degrees-of-freedom (DOFs) for shoulder and elbow joint movements. A monitor in front of the subject displays the exercises to be performed. A second monitor is dedicated to the operator.

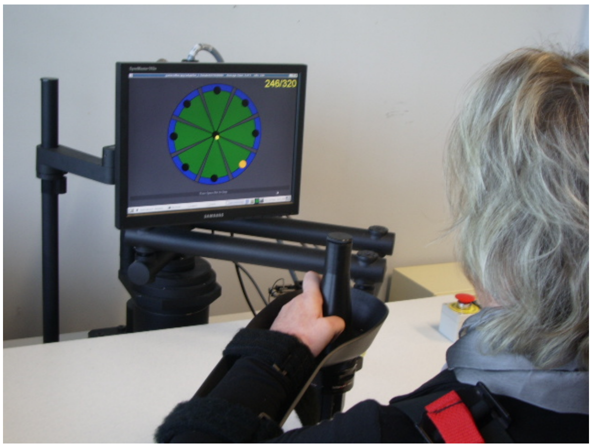

Figure 2. A patient during the robot-mediated therapy (standard robotic therapy rehabilitative scenario)

The workstation is mounted on a custom-made adjustable chair, designed to facilitate transfer of wheelchair-bound patients. The chair includes seat-belts to limit torso movements and an adjustable footrest.
Subjects held the end-effector of the robot through a handle; they were seated so that the center of the range of targets, lying approximately at the center of their reachable workspace, was aligned with the shoulder in the proximal-distal direction (y-axis).
During the therapy the subject's hemiparetic arm was placed in a customized arm support attached to the end-effector of the robot arm.
All subjects were asked to perform goal-directed, planar reaching tasks that emphasized shoulder and elbow movements.
As they attempted to move the robot's handle toward designated targets, the robot was able to recognize active component of movement: in this case it allows the patient to perform the movements without any support.
When the patient is unable to reach to the target, the robot supports the patient by driving the end-effector to the target.
The computer screen in front of the patient provided a visual feedback of the target location and the movement of the robot end-effector (Figure 2).

C. Intervention

Subjects in Group A were asked to perform goal-directed, planar reaching tasks, which emphasized shoulder and elbow movements, moving from the center target to each of eight peripheral targets (”clock-like” robotic therapy) (Figure 3).

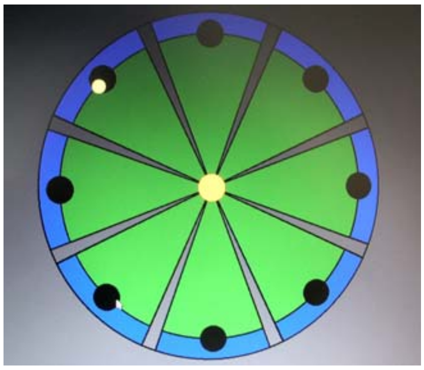

Figure 3. The standard “clock-like” robotic therapy rehabilitative scenario

Subjects in Group B performed the training using an innovative scenario, named “fan-like” robotic therapy, consisting of seven peripherals and a center target (Figure 4).
This scenario was implemented in order to reduce the stimulation of the upper limb flexor pattern avoiding a reinforcement of pectoralis and biceps muscles. For this reason, the directions and the length of the movements have been modified aiming at reducing the activity of flexor muscles and improving the extension of the arm. Compared to the “clock-like” scenario, the elbow joint range of motion (ROM) was reduced.
In each session subjects received 45 minutes of robot-mediated therapy, 3 sessions per week for 6 weeks. Both robotic therapy was composed of two different kind of exercises, unassisted (*Record*) and assisted movements (*Adaptive*). In details:

- *Record*: a series of 16 unassisted repetitions (“clock-like”) and 14 unassisted repetitions (“fan-like”) to each robot target. The goal is to reach toward each of the red targets shown on the monitor in front the patient . If the patient is able to reach the respective targets, the robot prompts him/her to move toward the next one. In the event the patient is unable to reach the target, the therapist pauses the device and move the patient arm passively to the next start position.

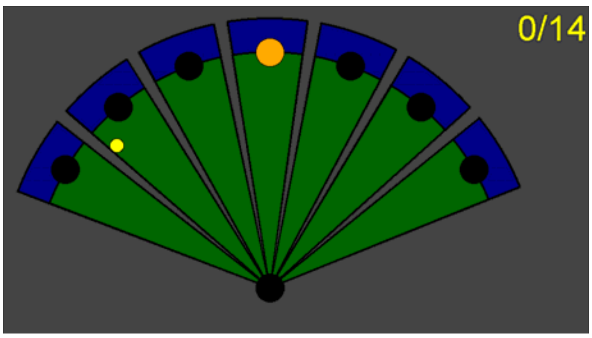

Figure 4. The innovative “fan-like” robotic therapy rehabilitative scenario

- *Adaptive:* a series of 320 assisted repetitions ("clock-like") and 280 assisted repetitions ("fan-like") to each robot target. The robot pre-positions the patient's arm at the center target when the program is activated. A visual performance display appears following five series of repetitions. Based on the patient performance, the program either increases or decreases the assistance provided to reach the targets.

Each session in both treatments was composed of 1) a series of assisted repetitions to each robot target (training test), 2) a series of unassisted repetitions to each robot target (*Record*), 3) three series of assisted repetitions (*Adaptive*). At the end of each *Adaptive* series, the patient is asked to perform a series of 16 unassisted movements (*Record*).

In each *Adaptive* series, following five series of repetitions, a visual display in front of the subject provides five quantitative scores based on her/his performance.

D. Outcome measures

The Motor Status Score for shoulder and elbow (MSS-SE), the Modified Ashworth Scale (MAS) for the elbow joint were used as outcome measures.

The MSS-SE expands the measurement of upper extremity impairment and disability provided by the Fugl-Meyer (FM) score and affords a reliable and valid assessment of upper limb impairment and disability following stroke [8]. The MSS-SE as a complete measure of upper limb isolated movements and motor function was administered to the subjects.

The Modified Ashworth Scale (MAS) [9] was used to assess muscle spasticity by rating the resistance to passive stretch.

A common condition in neurologically impaired patients is a pain in the shoulder joint [10], the amount of pain in the affected arm was assessed by using a 4-points verbal rating scale (0..3, where 0 represents no pain, 3 maximum pain) [11].

At the end of the robotic therapy participants from both groups were asked to answer a questionnaire about acceptability of the robotic therapy. The items in the questionnaire are related to the perceived degree of some aspects of robotic therapy, namely "Comfort", "Absence of pain", "Fatigue", "Enjoy", "Advantages", "Desire to continue", "Suggest to anyone".

Due to the features of the outcome scales (ordinal, but not equally ranged), a non-parametric statistical method, a Wilcoxon-Mann-Whitney test was used. All statistical analyses were performed with SPSS version.3.11.

III. Results

Before starting the treatments, Group A and Group B were homogeneous. An ANOVA performed on MSS-SE values at admission on both groups resulted in a not statistically significant difference (p=0,797).

After the treatments results show a significant decrease of motor impairment in paretic upper limb in both groups.

Statistically significant improvements were found on the MSS-SE measured before and after the robotic treatment in both groups (Group A, $p<0.05$, Group B, $p<0.05$).

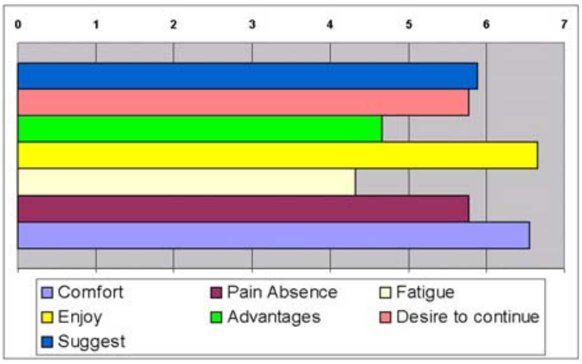

Figure 5. Group A subjects' acceptance of the robot-mediated therapy ("clock-like" robot therapy rehabilitative scenario)

The difference in the elbow MAS score between admission and discharge was statistically significant in both groups (Group A, $p<0.05$; Group B, $p<0.05$).

Changes in MSS-SE score both in Group A and Group B (Δ) between admission and discharge resulted in not statistically significant differences (ΔGroup A/Group B, $p>0.01$).

At the admission in the clinical trial, five subjects in Group A and five subjects in Group B suffered for a shoulder pain. Among those, at the end of the robotic therapy, all subjects showed a reduction in the pain score. One in Group A and three in Group B passed from 1 to 0, Four in Group A and two in Group B from 2 to 1. Any patient resulted in an increased score in the pain scale.

The averaged results from the questionnaire on the patients acceptance of the robot-mediated "clock-like" therapy (Group A) and "fan-like" therapy (Group B) is summarized in Figure 5 and Figure 6, respectively.

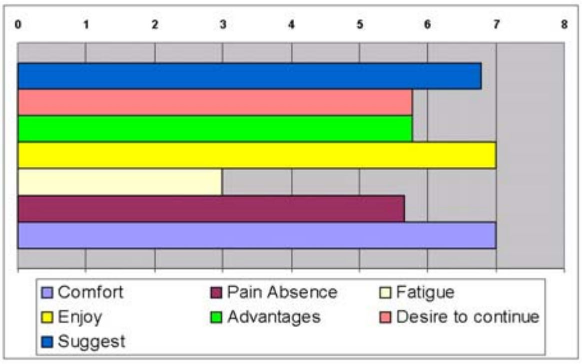

Figure 6. Group B subjects' acceptance of the robot-mediated therapy ("fan-like" robot therapy rehabilitative scenario)

No adverse events occurred during the whole operation time in and no patient withdrew.

IV. Discussion

The results confirm the effectiveness of robot-mediated rehabilitation treatments for elderly chronic hemiparetic patients and support the hypothesis that the improvements of motor abilities after a neurological injury can continue even more than one year after the acute event in elderly hemiparetic subjects.

Repetitive active movements did not caused an increase in the muscular tone. Our results confirms previous studies showing a reduction in spasticity after task- oriented training: in both groups, MAS score significantly decreased.

In elderly people, an increase in the elbow extension and a reduction of elbow flexion by using the “fan-like” scenario do not imply different results if compared to the “clock-like” scenario, where the elbow extension is reduced, whereas the elbow flexion is accentuated.

The robot-mediated therapy (both standard and “fan-like” therapies) was also well accepted and tolerated.

The improvement at the end of both proposed robot-mediated therapies support the hypothesis that in elderly subjects the increased stimulation of a specific joint was not a factor affecting the improvement of motor impairment.

V. Conclusions

The results confirm that the proposed innovative robot-mediated therapy contributes to decrease the upper limb’s motor impairment in elderly chronic neurologically impaired subjects. A reduction of the shoulder pain was observed too.

Furthermore, the implementation of different scenarios can also contribute to optimize and personalize robot-mediated rehabilitation therapies according to each patient’s specific motor impairment and the expected results.

In the elderly people, increasing the movement stimulation in a single joint, as in the “fan-like” scenario, do not yield an improvement of a specific movement, whereas multi-joint repetitive goal-directed movement seem to be more effective for a reduction of upper limb motor impairment. This aspect could be related to a change in motor control mechanisms due to the aging.

However, further studies (i.e., randomized controlled trials study design) are needed to better identify the mechanisms which are involved in the motor recovery in elderly subjects and to investigate how the robot-mediated therapy can improve functional motor abilities in activities of Daily Living (ADL).

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