ORIGINAL ARTICLE

Time-Course of Changes in Arm Impairment After Stroke: Variables Predicting Motor Recovery Over 12 Months

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ABSTRACT. Mirbagheri MM, Rymer WZ. Time-course of changes in arm impairment after stroke: variables predicting motor recovery over 12 months. Arch Phys Med Rehabil 2008;89:1507-13.

Objectives: To characterize the time-course of changes in motor recovery in the upper extremity of hemiparetic stroke survivors over a 1-year interval after stroke, and to use kinematic and kinetic recordings of elbow voluntary movement at 1 month to predict recovery over this 1-year period.

Design: Motor impairment was assessed using the Fugl-Meyer Assessment (FMA) of the upper extremity. The angular elbow movement trajectory and its derivatives were recorded. Limb kinetics were quantified using maximum voluntary contractions. Subjects were examined at 1, 2, 3, 6, and 12 months after stroke. The growth mixture model was used to characterize the recovery patterns of the FMA over 1 year, and a logistic regression analysis was used to predict these patterns with the kinematic and kinetic measures recorded at 1 month.

Setting: A hospital-based laboratory with a movement testing system including position and torque sensors.

Participants: Hemiparetic stroke survivors (N=20) with upper-extremity impairment recruited within 4 weeks poststroke.

Interventions: Not applicable.

Main Outcome Measures: Kinematic parameters, including active range of motion, peak velocity, peak acceleration, movement smoothness, and movement speed; kinetic parameters, including isometric voluntary contraction of elbow extensors and flexors; and clinical measurement of motor impairment (FMA).

Results: We found 2 classes of recovery patterns. Class 1 subjects started with a low-level FMA score and then increased quickly before tapering off gradually. Conversely, class 2 subjects started with a high-level FMA score that remained constant or increased slightly. Using logistic regression, the impact of each kinematic and kinetic measure on class membership was characterized. The class assignment helped predict the recovery pattern of motor impairment for each subject.

Conclusions: Using elbow kinematic and kinetic measures 1 month after stroke, we were able to predict accurately the recovery of arm impairment in subjects with hemiparetic stroke at different time points in the first year. This information is of potential value for planning targeted therapeutic interventions.

Key Words: Kinematics; Kinetics; Rehabilitation.

THE IMPAIRMENT AND FUNCTIONAL limitation that follow stroke are caused by disturbances in descending neural commands. Although the precise mechanisms that affect voluntary function are uncertain, clinical observations routinely show rapid recovery of neurologic status after stroke.[1,2] This recovery pattern has motivated study of the magnitude and time-course of this spontaneous recovery over the first few weeks after stroke.[2-7] Although many earlier longitudinal studies suggest that impairment recovery may reach maximum levels within a few weeks, there is no evidence to limit potential further improvements to this time frame. This possibility is also supported by studies that report the nonlinear time-course of the recovery patterns of neurologic impairments and functional limitations.[6,7] Furthermore, previous longitudinal studies evaluated the group average recovery pattern, which does not necessarily reflect possible variations in time-course in subpopulations of patients. It follows that the natural history of motor recovery is not well characterized, and therefore not fully understood.

The first aim of this study was to characterize the time-course of changes in motor impairments of the upper extremity, as assessed by the FMA,[8] by identifying patient subpopulations that showed different patterns of recovery over a longer period after stroke (eg, 1y).

The second aim was to develop robust predictors of clinical outcome, again over a longer interval after stroke. A few studies have attempted to find features that can serve as good prognostic predictors, but most are not easily implemented.[9,10] We therefore searched for simpler and more practical predictors. We tested several kinematic and kinetic measures, such as the active ROM and maximum isometric voluntary contraction torque to predict recovery. Using this approach, we could accurately predict the recovery pattern for each subject on the basis of measurements made at the first visit (ie, 1 month after stroke).

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Supported by the National Institutes of Health (grant no. 1 R21 NS45005-01A1), the American Heart Association (grant no. SDG 0330166N), and the National Science Foundation (grant no. NSF 0302313).

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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Published online June 30, 2008 at *www.archives-pmr.org*.

0003-9993/08/8908-00911$34.00/0
doi:10.1016/j.apmr.2008.02.017

List of Abbreviations

CI	confidence interval
FMA	Fugl-Meyer Assessment
MAS	Modified Ashworth Scale
MVC	maximum voluntary contraction
NS	not significant
OT	occupational therapy
PT	physical therapy
ROM	range of motion

Table 1: Characteristics of Stroke Subjects

Subject	Age (y)	Sex	Stroke Hemisphere	Stroke Type
S1	39	Female	Right	Hemorrhage
S2	73	Female	Left	Hemorrhage
S3	72	Female	Right	Hemorrhage
S4	62	Female	Left	Hemorrhage
S5	78	Male	Left	Hemorrhage
S6	77	Female	Left	Hemorrhage
S7	51	Female	Left	Ischemia
S8	65	Male	Right	Ischemia
S9	75	Male	Right	Hemorrhage
S10	60	Male	Left	Hemorrhage
S11	57	Female	Right	Hemorrhage
S12	66	Male	Right	Hemorrhage
S13	61	Male	Right	Ischemia
S14	70	Male	Left	Hemorrhage
S15	42	Male	Right	Ischemia
S16	73	Male	Left	Hemorrhage
S17	61	Male	Left	Ischemia
S18	68	Female	Right	Ischemia
S19	60	Male	Left	Hemorrhage
S20	72	Male	Left	Ischemia
Mean ± SD	64.1±10.8	12 Male/8 female	9 Right/11 left	13 Hemorrhage/7 ischemia

METHODS

Subject Recruitment and Clinical Assessment

Twenty survivors of hemiparetic stroke (64.1±10.8y) were recruited within 4 weeks after a stroke. The characteristics of the subjects are summarized in table 1.

Subjects with stroke were drawn from the inpatient service of the Rehabilitation Institute of Chicago. The sample consisted of consecutive cases satisfying the inclusion criteria. Our rate of declination was approximately 10%, primarily because of travel constraints. Our population reflected the stroke population at large, and there was thus no indication of sampling bias.

Patients met the following inclusion criteria: (1) absence of aphasia or cognitive impairment, (2) normative tone and no motor or sensory deficits in the nonparetic arm, (3) absence of severe muscle wasting or of dense sensory deficits in the paretic upper limb, (4) presence of spasticity in the involved elbow muscles, (5) ability to perform even limited elbow extension and flexion at first assessment, and (6) no previous stroke history. All subjects gave informed consent to the experimental procedures, approved by the institutional review board of Northwestern University.

All subjects received intensive PT and OT from our stroke team: 1 hour each of PT and OT for 6 days a week for about 3 weeks, as acute inpatients, and 1 hour 3 times a week each of PT and OT for 2 months after discharge, followed by 1 to 2 hours a week of each for an additional 2 to 3 months thereafter.

Survivors of stroke were assessed clinically before each experiment using the 5-point MAS to assess muscle tone[11] and the 66-point FMA to assess motor impairment.[8] These scales are widely used clinical assessment instruments.

Experimental Procedure

A description of the apparatus is provided elsewhere.[12] Subjects were strapped to an adjustable chair with the forearm attached to a beam mounted on a torque cell, through a custom fitted fiberglass cast. Shoulder abduction was 80°. The elbow rotation axis was aligned with the axis of the torque sensor and potentiometer.

Subjects moved the forearm voluntarily from full elbow flexion to extension at maximum speed. These movements were repeated 5 times and ensemble-averaged. The experiment was repeated at 5 time points after stroke onset (ie, at 1, 2, 3, 6, and 12 months postinjury).

Elbow position (fig 1A) and torque were recorded with a precision potentiometer and torque transducer. An elbow angle of 90° was set as the neutral position and defined as 0. Position and torque signals were filtered at 230Hz to prevent aliasing and sampled at 1kHz by a 16-bit analog-to-digital converter.

Data Analysis

Study participants were asked to generate an isometric MVC in elbow extension and flexion at the neutral position for 5 seconds, and the output was recorded. The process was performed 3 times, and measurements were averaged.

Angular velocity and acceleration were calculated from the first and second derivatives of the elbow angular position data, respectively (figs 1B, 1C). These data were used to quantify movement kinematic parameters: peak velocity, peak acceleration, movement speed, active ROM, and movement smoothness.[12]

Impaired voluntary movements are characterized by these parameters, including a loss of smoothness in movement trajectory.[13,14] In nonparetic arms, rapid voluntary movement trajectories are smooth (see fig 1A) with single-peaked, bell-shaped velocity profiles (see fig 1B). In contrast, movement trajectories of paretic limbs are rippled (see fig 1A) with multiple peaks and irregularities in both velocity (see fig 1B) and acceleration (see fig 1C).

Statistical Analysis

We used the growth mixture model[15-20,a] to find the recovery patterns (class) for FMA over 1 year. In our earlier study, we have demonstrated the validity of this model applied to the kinematic and kinetic data.[21] The growth mixture model as-