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ORIGINAL ARTICLE

Motor Recovery of the Ipsilesional Upper Limb in Subacute Stroke

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Abstract

Objective: To investigate the time-related changes in motor performance of the ipsilesional upper limb in subacute poststroke patients by using clinical and kinematic assessments.

Design: Observational, longitudinal, prospective, monocentric study.

Setting: Physical medicine and rehabilitation department.

Participants: Stroke patients (n=19; mean age, 62.9y) were included less than 30 days after a first unilateral ischemic/hemorrhagic stroke. The control group was composed of age-matched, healthy volunteers (n=9; mean age, 63.1y).

Interventions: Clinical and kinematic assessments were conducted once a week during 6 weeks and 3 months after inclusion. Clinical measures consisted of Fugl-Meyer Assessment, Box and Block Test (BBT), Nine-Hole Peg Test (9HPT), and Barthel Index. We used a 3-dimensional motion recording system during a reach-to-grasp task to analyze movement smoothness, movement time, and peak velocity of the hand. Healthy controls performed both clinical (BBT and 9HPT) and kinematic evaluation within a single session.

Main Outcome Measures: BBT and 9HPT.

Results: Recovery of ipsilesional upper arm capacities increased over time and leveled off after a 6-week period of rehabilitation, corresponding to 9 weeks poststroke. At study discharge, patients demonstrated similar ipsilesional clinical scores to controls but exhibited less smooth reaching movements. We found no effect of the hemispheric side of the lesion on ipsilesional motor deficits.

Conclusions: Our findings provide evidence that ipsilesional motor capacities remain impaired at least 3 months after stroke, even if clinical tests fail to detect the impairment. Focusing on this lasting ipsilesional impairment through a more detailed kinematic analysis could be of interest to understand the specific neural network underlying ipsilesional upper-limb impairment.

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Stroke is the leading cause of long-term disability among adults,[1] with up to 50% of survivors having residual sensorimotor deficits.[2] Besides the primary deficit of the contralesional upper limb (UL), the presumed-to-be "unaffected" UL is known to show weakness of the proximal arm muscles, slowing, and clumsiness.[3-5] Jung et al[6] demonstrated that patients with weakness of the ipsilesional UL maximally recovered within 1 month poststroke but remained impaired in comparison with controls. Other studies[7,8] reported recovery of ipsilateral hand function over 3 to 4 months. Persistent impaired reaction time within the first year poststroke has been shown,[9] indicating that ipsilesional UL deficits might not be a temporary event.[6,10] However, little is known about the time course evolution of ipsilesional motor recovery, and even less about its implications for rehabilitation.[5,11]

Controversies exist about the most accurate way to assess the subtle ipsilesional motor dysfunction. Although Morris and van Wijck[12] assumed that common clinical scales (eg, Nine-Hole Peg Test [9HPT], Action Research Arm Test) were appropriate to track ipsilesional deficits, other studies[13,14] reported that most clinical tests appeared unable to detect fine changes in motor performance.

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Metrics extracted from kinematics are strongly assumed to accurately quantify ipsilesional motor changes in reaching movements over time,[15-17] leading to insights into the process of motor recovery after stroke.[18] Kinematics may show some improvements in movement features that cannot be clinically detected.[19] This implies that time-sensitive changes may be only visible using kinematics. Therefore, combining kinematics with clinical measures seems valuable.

Because brain function differs between hemispheres, lesion side is a factor to be considered. The right hemisphere seems to play a leading role in inducting the spatial task demands into movement preparation and execution. In contrast, the left hemisphere plays a special role in movement programming under action constraints.[20] Therefore, damage in the left hemisphere (LHD) or in the right hemisphere (RHD) may produce distinct ipsilesional reaching deficits. To better identify the neural networks underlying these differences in impairments, previous studies investigated the influence of the side of the lesion on ipsilesional sensorimotor deficits. In several studies,[21-23] similar outcomes were found irrespective of the side of the damaged hemisphere. Yet, Baskett et al[24] showed that RHD patients exhibited worse performances on ipsilesional finger tapping compared with LHD patients and controls. A more recent study[25] reported that ipsilesional control of UL trajectory of LHD patients was impaired because of a failure in coordination of joint synergies. Conversely, RHD patients did not show impairment in trajectory control but exhibited deficits in final position accuracy.[25] Therefore, understanding recovery of the ipsilesional UL requires taking into account the side of the lesion.

The purpose of our study was to provide a detailed longitudinal analysis of the sensorimotor and functional recovery of the ipsilesional UL at the subacute stage of a stroke through weekly repeated measures. Based on previous findings, we expected that (1) the ipsilesional UL function would improve over time but still remain impaired compared with control subjects at study discharge; and (2) the side of the stroke damage would influence deficits observed on the ipsilesional UL.

Methods

Participants

Nineteen patients (16 men; mean age ± SD, 62.9±9.9y) were systematically included within the first month poststroke (mean ± SD, 20.8±6.8d). Ten were LHD and 9 were RHD. All patients were right-handed before the stroke. Inpatients were included in the protocol from June 2009 to May 2010 in the Department of Physical and Rehabilitation Medicine of the CHU Nîmes in Le Grau du Roi (France). Inclusion criteria were as follows: (1) first unilateral ischemic or hemorrhagic supratentorial stroke; (2) no serious cognitive deficits (Mini-Mental State Examination score[26] >25); (3) no serious aphasia; and (4) no neglect behavior (Catherine Bergego Scale[27] <15/30). All patients provided informed consent, approved by the Institutional Review Board of the Hospital of Nîmes. The study protocol was approved by the South Mediterranean III Ethical Committee.

Nine age-matched healthy controls (6 men; mean age ± SD, 63.1±7.3y) with an absence of previous neurologic or orthopedic disease were included. All controls were right-handed. All participants were blind to research hypotheses. Overall participants' characteristics are reported in table 1.

List of abbreviations:

BBT	**Box and Block Test**
FMA	**Fugl-Meyer Assessment**
LHD	**left hemisphere damaged**
9HPT	**Nine-Hole Peg Test**
NVP	**number of velocity peaks**
rANOVA	**analysis of variance with repeated measures**
RHD	**right hemisphere damaged**
UL	**upper limb**

Experimental design

Patients performed 8 sessions of assessment once a week over 6 weeks starting from inclusion (week 0) to an intermediate step (week 6), and a follow-up assessment (week 12). No specific ipsilesional UL training was addressed during this period.

Assessments

Clinical evaluation

The Fugl-Meyer Assessment (FMA; maximum score, 66) was conducted to evaluate motor recovery of the contralesional upper arm.[28] Its construct validity and high inter- and intrarater reliability properties have been demonstrated.[29]

To address global functional capacities, we used the Barthel Index,[30] which is a validated quantitative scale (maximum score, 100).

The Box and Block Test (BBT) and the 9HPT were performed in both healthy and stroke patients. Control subjects performed the 2 tests within a single assessment with the dominant and nondominant UL.

The BBT is a standardized and quantitative validated test that quantifies gross UL dexterity.[31] The participant was required to move, 1 by 1, the maximum number of blocks from one compartment of a box to another of equal size within 1 minute. Normative scores in 75-year-old healthy controls are considered 61 blocks per minute.[31]

The 9HPT was used to measure fine UL dexterity. It is a timed, standardized, quantitative test requiring coordinated reaching and precision finger grip.[32] Normative times are described between 19 and 22 seconds.[33]

Because the above reference values depend on age and hand dominance,[33] we chose to recruit age-matched, healthy, right-handed controls for a single assessment, during which they performed the BBT and 9HPT.

Kinematic evaluation

A kinematic analysis of a reach-to-grasp task was added to assess motor recovery during an "as functional as possible task." Participants were asked to grasp a 5-cm ball lying on a horizontal surface 25cm away from the hand with the ipsilesional UL, at a self-selected, comfortable speed. After 2 practice trials, participants performed 5 trials in a row. Kinematic information was recorded with a 3-dimensional motion system (Fastrak[a]) that used 2 electromagnetic sensors to record 3-dimensional positions (x,y,z) at 30Hz. A sensor was placed on the head of the third metacarpal of each hand, aligned with the metacarpal axis. Only the reaching part of the reach-to-grasp movements was analyzed. Based on prior studies,[34-36] we chose to analyze the number of velocity peaks (NVP), the movement time, and the peak value of hand velocity. Fully detailed information is provided in Metrot et al.[36]