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Case Report Open Access

Stroke Recovery after Unilateral Posterior Spinal Artery Stroke: A Case Report

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Abstract

Background and Purpose: The present report details the acute history and functional recovery of a patient with a rare ischemic infarction of the posterior spinal artery affecting the right posterior column and descending lateral motor tracts in the uppermost cervical spinal cord.

Summary of Case: The patient presented with significant unilateral sensory ataxia and hemiparesis. We monitored the patient's recovery for six months using standard clinical assessments and novel robotic measures of sensorimotor impairment.

Conclusion: There are challenges in accurately monitoring stroke recovery, in particular sensory recovery. This case highlights the potential for new robotic assessment tools.

Keywords: Stroke recovery; Spinal artery stroke

Case Report

A 67 year-old right-handed man with dyslipidemia experienced sudden neck pain and nausea while watching television. He reached for his neck and noticed numbness of his right hand, weakness of his right arm and right leg weakness with gait instability. Although he had chronic neck pain, he had no recent trauma or therapy for his neck.

On arrival to hospital, motor power was grade 3 of 5 on the MRC Scale [1] (where 0 = no movement and 5 = muscle contracts against full resistance) in his right hand, and 4 of 5 in his proximal right arm. Power in his right leg was 4 of 5 in a pyramidal distribution. Sensory deficits were noted on the right side involving joint proprioception as well as light touch across spinal levels C2-T4. Pinprick and temperature sensation appeared slightly decreased. Ataxia was noted in both right arm and leg. Rapid finger tapping and alternating movements in the right hand were slowed. The National Institute of Health Stroke Scale (NIHSS) score was 4.

Initial computed tomogram (CT) and CT angiogram of his head and neck showed no signs of acute infarct or occlusion. Subsequent Magnetic Resonance imaging (MRI) revealed an area of restricted diffusion at the level of the right cervical-medullary junction posteriorly extending to the second (C2) level of the cervical cord (Figure 1). This represented acute infarction of the right posterior hemicord in the posterior spinal artery branch distribution. Stroke etiology was determined to be cryptogenic after an extensive workup.

During the initial week post-stroke, muscle strength improved in the right arm and leg. In spite of this, he struggled with activities of daily living. He was transferred to the subacute rehabilitation unit, and discharged home one month later.

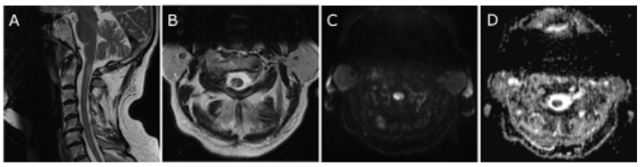

Figure 1: A. Sagittal T2 MRI showed hyperintense signal from the cervical-medullary junction to C2 level. B. Axial T2 MRI at C1-C2 level showed hyperintense signal in the right posterior hemicord following strict midline cut-off in a posterior spinal artery distribution. C. DWI map at C1-C2 level showed hyperintense signal consistent with restriction in diffusion caused by ischemic infarct. D. ADC map at C1-C2 level showed hypointense signal consistent with restriction in diffusion caused by ischemic infarct.

Methods

Standardized clinical and robotic assessments were completed 8, 39, 85 and 183 days post-stroke.

Clinical Assessment

A stroke clinician, blinded to the robotic assessment, performed clinical assessments. At all time points, clinical exams included tests of motor power (MRC 5 point scale) [1], dexterity (Purdue pegboard) [2], position sense (The thumb localization test) [3], impairments of the hand and arm (The Chedoke-McMaster Stroke Assessment (CMSA)) [4] and activities of daily living (The Functional Independence Measurement (FIM)) [5]. At the first time point a Montreal Cognitive Assessment (MoCA) [6] score and visual acuity were determined.

Robotic Assessment

We assessed the subjects upper limb sensory and motor function using the KINARM bilateral exoskeleton robot (BKIN Technologies Ltd, Kingston, ON, Canada), a robotic device that provides gravitational support of the arms, permits movements in the horizontal plane, monitors shoulder and elbow motion, and if required can move the arm in the workspace [7,8]. The augmented reality system of the KINARM superimposes computer-generated visual targets in the same plane as the subjects' arms. This allows for the subject to realistically interact with these targets, similar to virtual reality, but without completely immersing them into a digital environment. The subject completed two assessment tasks with the robot, detailed below.

In the visually-guided reaching task, the subject was asked to make unassisted reaching movements "quickly and accurately" from a central target to 1 of 8 peripheral targets located 10cm away. Each target was presented once in a randomized block and eight blocks were collected. The full methods for this technique and evaluation of its reliability have been previously described [9]. Nine parameters were evaluated: 1) postural speed (PS) (m/s) is the mean hand speed for 500 ms before peripheral target illumination. This parameter allows for identification of postural tremor. 2) Reaction time (RT) is the time between illumination of the peripheral target and onset on movement. This parameter identifies subjects who are slow to initiate movement post-stroke. 3) Movement time (MT) is the total time elapsed from movement onset to offset. 4) Maximum speed (MS) is the fastest speed the hand traveled during the reaching movement. Many patients move slowly after stroke, which is detected by MT and MS. 5) Initial direction error (IDE) is the angular deviation between a straight line from the hand position at movement onset to the hand position after the initial phase of movement. This parameter helps to detect those subjects who have impaired control of spatial aspects of movement initiation. 6) Initial distance ratio (IDR) is ratio of the distance the hand traveled during the participant's initial movement to the distance the hand traveled between movement onsets and offset. A ratio closer to 1 implies the initial movement was closer to being a single movement to the target requiring a minimal corrective sub-movement(s) to reach the target. We commonly see patients post-stroke who make multiple corrective movements to reach the target and thus end up with a lower IDR. 7) Initial speed ratio (ISR) is the maximum hand speed of the initial movement compared to the global hand speed maximum of the trial. A ratio close to 1 implies the initial movement was closer to being a single movement, 8) Number of speed peaks (NSP) is the number of speed maxima between movement onset and offset. This parameter allows determination of the number of corrective movements a subject must make to accomplish the reach. 9) Min-max speed difference (MSD) is the difference between local speed peaks and minima. This parameter allows identification for variability in movement speed that we have observed in many stroke patients in the past. These parameters underlie three attributes of basic visuomotor control: postural control, visuomotor reaction, and movement control.

Figure 2A shows the performance of a control subject for visually-guided reaching to help illustrate normal behavior. Note the fairly straight hand paths for all movement directions. Hand speed plots show an early single large peak, with small corrective movements near the end.

In the arm position matching task, the subject's vision of the limbs was occluded. He relaxed his right arm (passive hand, side affected by the stroke) and let the robot move it to 1 of 9 different spatial locations. When the robot stopped moving, the subject was given unlimited time to move his unaffected hand (active hand) to the mirror location in space. Nine target locations were randomized within a block and six blocks were collected. The full methods for this technique and evaluation of its reliability have been previously described [10].

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The parameters evaluated include: 1) Variability (Var) is the trial-to-trial consistency of the active hand's end position. We often see this increased following stroke. 2) Spatial contraction/expansion (C/E) is the area of the workspace matched by the active hand relative to the passive hand moved by the robot. We often see this decreased following stroke. 3) Systematic shifts (Shift) are the constant errors between the active hand and the robotically moved passive hand. These parameters have been previously shown to highlight position sense deficits in individuals with stroke [10].

Figure 2B shows the performance of a control subject for the arm position matching task with passive hand positions mirrored onto the active hand positions for better visualization. The difference between the expected and actual hand positions is relatively small and the small size of the ellipses denotes good trial-to-trial repeatability (low variability) in hand positions. In many stroke patients the size of these ellipses can be quite large. Overall, the square area served by the active arm closely matches that of the passive arm without any systemic shifts of the target set or any spatial contraction/expansion.

Normative data for each robotic assessment was collected from 170 healthy individuals and linear regression models considered the candidate's age, handedness and sex for each parameter.

Results

Baseline MoCA was 26/30, losing 3 points on recall and 1 point on day of the week. Vision was 20/30 uncorrected. In the first 2 test sessions (days 8 and 39), he had 4/5 power at the right shoulder (flexion, extension, abduction, and external rotation), the wrist (flexion), and the fingers (extension, abduction). By day 85, all right arm muscles were 5/5. Longitudinal scores on the Purdue pegboard, thumb localization test, CMSA and FIM are shown in Table 1. He could not perform the pegboard test with his right arm during the first assessment. Initially he had severe difficulty in the right thumb localization test indicating impaired proprioception, but his score normalized by day 85. Despite having full power on day 85, his CMSA scores were abnormal, but normalized by day 182 post-stroke. Despite patient complaints of functional deficits, the FIM score remained high throughout and attained a maximal value of 126 by day 85.

Figure 3A shows the patient's hand trajectories and speed profiles during reaching. On day 8, he exhibited multiple abnormalities in this task including large initial direction errors and slowed movements, which improved over time. Overall, the patient's performance on the reaching task progressively improved and all parameters were within normal limits by day 183.

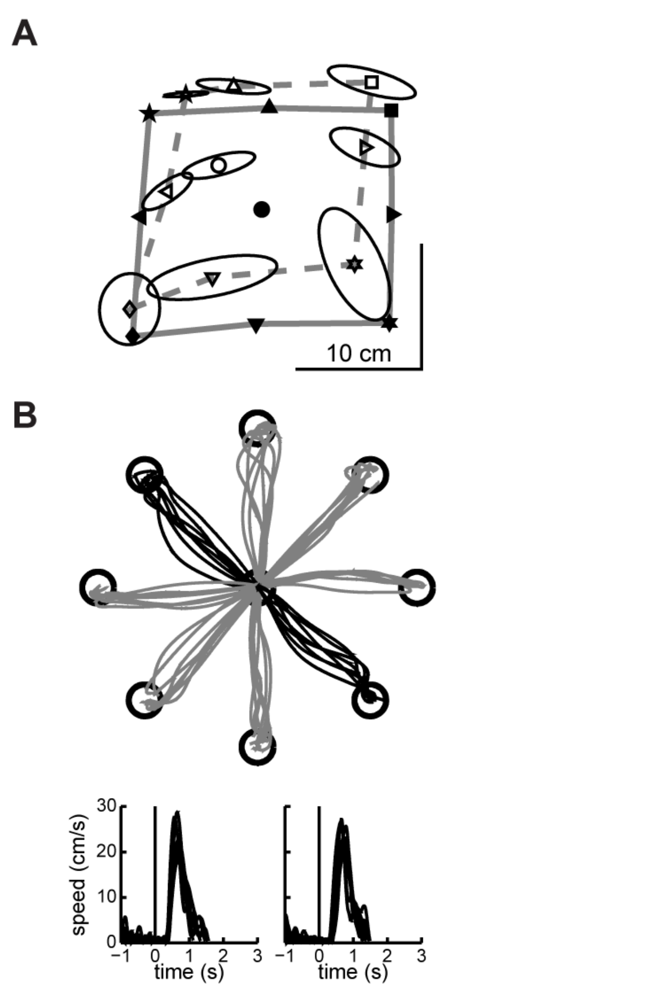

Figure 2: A)Arm position matching in a healthy control subject. For presentation purposes only we have transposed the target locations of the robotically moved hand (filled symbols) and overlaid them on the locations where the subjects moved the opposite active hand (open symbols). Ellipses denote trial-to-trial variability. B) Top: hand paths for visually-guided reaching movement from central target to one of eight peripheral targets in a normal control subject. Bottom: hand speed profiles for movement towards left upwards and right downwards directions respectively, with time zero denoting onset time of visual target.

Figure 3B displays the patient's performance in the arm position matching task. At day 8 post-stroke he had significantly increased variability, visualized by the large standard deviation ellipses. Further the target set was spatially contracted as demonstrated by the fact the area of the workspace moved through by the active hand was substantially smaller than that of the area of the robotically moved hand. Although the variability improved over time, the spatial contraction parameter remained abnormal at day 183 post-stroke.

Individual performance metrics for all parameters for both robotic tasks and all time points for the case are depicted in Table 2.

	Day 8	Day 39	Day 85	Day 182
Purdue pegboard(No. of pegs in 30 secs)	13 / 0	14 / 2	11 / 4	13 / 3
Thumb localization	1 / 3	0 / 2	0 / 0	0 / 0
CMSAh	7 / 5	7 / 5	7 / 5	7 / 7
CMSAa	7 / 4	6 / 6	7 / 6	7 / 7
FIM	120	124	126	126

Table 1: Clinical tests and scales (Left/Right)

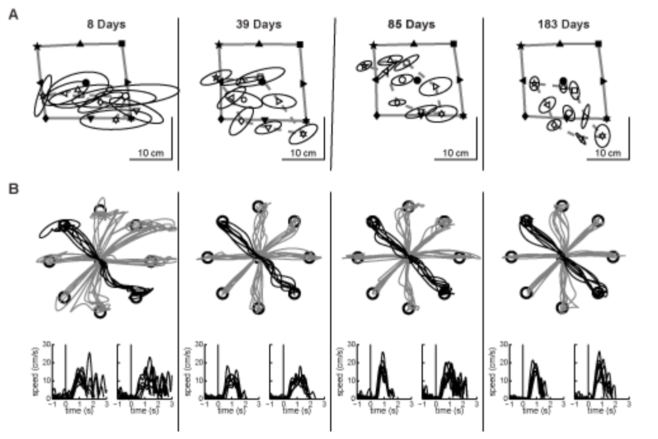

Figure 3: A) Patient's performance in the arm position matching task across four time points. As in Figure 2A, mean hand positions are shown by closed symbols (passively moved right arm) and open symbols (active left arm). B) Patient's performance using right arm in the visually-guided reaching task.

Any values that fall outside the 95% range of normal controls are bolded. We display these measurements in comparison to normalized values in Figure 4 to allow comparison to control behavior.

Discussion

We document the recovery of an individual with a rare case of cervical spinal cord stroke affecting the right posterior column and descending lateral tracts. While lesions in either pathway can generate immediate impairments in motor function, sensory deficits are expected only from damage to the former pathway [11]. Recovery of some motor function may have occurred, in part, by compensation from medial motor pathways and increased use of visual feedback. However, the fact that fine motor deficits persisted (based on PPB) likely reflected incomplete compensation of the medial motor

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pathways and/or the inability of vision to compensate for loss of cutaneous feedback of skin contact forces during object manipulation [12]. Further, he continued to have significant proprioceptive deficits that also likely impacted fine motor control.

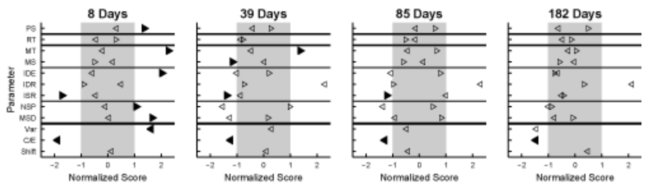

Figure 4: Patient's normalized scores plotted against the normative reference range (grey shaded area) established from normative data. Normalized score of -1 denotes 5th percentile, 0 denotes median value, and 1 denotes 95th percentile for healthy individuals. The first 9 parameters are derived from the visually-guided reaching task, and the last 3 are from the arm position matching task. Rightward and leftward triangles are used for right and left hand movements respectively. Acronyms defined in Methods.

Task	Parameter	Time Post-Stroke			
		8 Days	39 Days	85 Days	182 Days
Reaching	PS (cm/s)	0.53 | **0.87**	0.35 | 0.40	0.40 | 0.62	0.31 | 0.58
(L | R)	RT (ms)	342 | 404	314 | 320	362 | 338	340 | 363
	MT (ms)	952 | **1947**	883 | **1394**	890 | 1190	938 | 1017
	MS (cm/s)	26.6 | 19.5	23.9 | **14.3**	26.0 | 18.7	23.0 | 18.8
	IDE (deg)	3.67 | **9.88**	2.96 | 5.16	2.87 | 6.69	3.55 | 3.35
	IDR	0.84 | 0.66	0.89 | 0.66	0.94 | 0.66	0.90 | 0.78
	ISR	0.97 | **0.92**	0.96 | **0.94**	1.00 | **0.94**	0.97 | 0.97
	NSP	2.36 | **3.02**	1.56 | 2.97	1.66 | 2.70	1.86 | 1.92
	MSD (cm/s)	0.64 | **3.70**	0.00 | 0.01	0.00 | 0.02	0.00 | 0.00
Matching	Var (cm)	**7.00**	4.30	3.20	2.10
	C/E	**0.04**	**0.37**	**0.33**	**0.30**
	Shift (cm)	5.20	5.00	3.00	7.10

Table 2: Robotic test results

This case helps to illustrate how robotic and other assessment tools (i.e. PPB) can be helpful in identifying and monitoring sensory and motor function. The relationship between our robotic measures and clinical measures is one of interest, but is difficult to evaluate quantitatively in a single case study. In a previous study, we evaluated a group of one hundred subjects with stroke and showed modest to moderate correlations between performance on various task parameters in the visually guided reaching or position matching tasks and common clinical measures such as the PPB and the FIM [13]. In that study the visually guided reaching parameters demonstrated a Pearson's correlation coefficient of 0.61 between the Movement Time parameter with the Purdue Pegboard, but only 0.35 with the Reaction Time parameter and no significant correlation with the robotic Posture Speed variable. When comparing robotic tasks with the FIM in that study, we also saw similar variability in the strength of correlations. For example position matching Shift had a Pearson's correlation coefficient of -0.41 versus C/E which as non-significant. The variability observed in the correlation coefficients between robotic measures and more traditional clinical measures is not, however, entirely unexpected. Many individuals can complete the majority of the tasks in the FIM one-handed. Further, the FIM, like many other clinical tests that are commonly used, can suffer from ceiling effects and poor sensitivity to detect small but functionally relevant deficits [14]. Many clinical tests use ordinal scales where the top number is assumed to represent normal function. For example, despite continued complaints of problems using a spoon and toothbrush, our subject's CMSA, a tool specifically developed for assessing arm and hand function, attained the maximal score at 6 months. Fundamental issues with the basic measurement properties of any given assessment can lead to problems in accurately identifying a subject's deficits [13]. In our study case, the robot and PPB scores, which are both based on normative scales identified impairments consistent with these problems in daily activities.

Ultimately, better insight into the level and nature of dysfunction of a given patient allows optimization and tailoring of the rehabilitation process to the individual. In our opinion, this will only come from the development of better measurement tools than are currently used in many areas of stroke rehabilitation. Robotic technology represents one potential method to accurately quantify human behavior with very specific outputs and we believe its use warrants further investigation.

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Disclosure

Author SHS is the co-founder and scientific officer of BKIN technologies, the company which manufactures the KINARM robotic device.

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