

A Pianist's Recovery From Stroke

James F. Toole, MD; D. Lynn Flowers, PhD; Jonathan H. Burdette, MD; John R. Absher, MD

Objective: To determine alternative neural pathways for restitution of piano playing after right hemispheric infarction causing left arm and hand paralysis.

Design: Case report testing coordinated bimanual skills using structured motor skills tests and neuroimaging.

Setting: A professional pianist sustained a lacunar infarction in the posterior limb of his right internal capsule, which resulted in left hemiparesis with immobilized left-hand and -finger movements persisting for 13 weeks. After 6 months, he had recovered bimanual coordinated piano skills by "ignoring" his left hand while concentrating or discussing subjects other than music while playing.

Patient: A 63-year-old, male professional pianist.

Intervention: Detailed neurological examination including computed cranial tomography, functional magnetic resonance imaging, and positron emission tomography.

Results: Functional magnetic resonance imaging activation patterns correlated with rapid movements of fingers in each hand separately and together demonstrating that subcortical and cerebellar pathways were activated during skilled motor function of his left hand. Contralateral cerebral and cerebellar activation occurred with both left- and right-hand movements. During tapping of the left fingers, there was bilateral cerebellar, parietal, and left premotor strip and left thalamic activation.

Conclusion: Patterns of activation relate to task performance and they are not similar to subjects engaged in simpler tasks such as finger opposition.

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THERE HAS BEEN GREAT INTEREST in the neurological disabilities of musicians garnered prior to modern methods for neurological localization.¹⁻³ Some have suggested that musicians with enhanced motor skills possess greater capacity for plasticity because of enriched interhemispheric connections⁴⁻⁹ or structural asymmetry of relevant brain areas.^{10,11} We present the functional magnetic resonance imaging (fMRI) findings of a professional musician rendered left hemiplegic by a lacunar infarction in the posterior limb of his right internal capsule, adjacent to but sparing the thalamus, after he recovered fine motor skills in the fingers of his paralyzed hand.

REPORT OF A CASE

A 63-year-old, male, right-handed professional pianist developed sensory loss, weakness, and dystaxia of his nondominant left arm and hand. Despite physical

therapy, he did not regain his ability to play the piano bimanually, and the harder he tried, the more disabled he became. During sleep, his wife noticed the left-hand fingers moving. She wakened him and asked what he was playing. As soon as he became alert, voluntary movements stopped. Thereafter, he "ignored" his left hand while focusing his attention on his right. Thirteen weeks later, he successfully used this technique in a public performance.

Eighteen months later, findings from the neurological examination were normal except for increased stretch reflexes and a Babinski sign on his left side. Detailed assessment did not reveal callosal disconnection, ideomotor apraxia, or alien hand syndrome. Neurobehavioral and neuropsychological tests found verbal ability to be higher than the 92nd percentile and nonverbal, in the 50th percentile, without impairment of memory, attention, auditory skills, silent reading comprehension, and writing to dictation. Manual dexterity was tested in the standardized fashion using the grooved pegboard task

Author Affiliations:

Departments of Neurology (Drs Toole and Flowers) and Radiology (Dr Burdette), Wake Forest University Medical Center, Winston-Salem, North Carolina; and Absher Neurology PA, Taylors, South Carolina (Dr Absher).

and other standardized assessment instruments including finger opposition, finger-to-nose, finger-nose-finger, and rapid alternating movements. He was tested while he ignored his left hand during observation of his piano playing unilaterally and bilaterally. Sensory discrimination using objects placed in a bag revealed that he could name 2 of 5 correctly. Manual dexterity and endurance were in the 99th percentile on the right side and slightly higher than average on the left side. Graphesthesia, stereognosis, tactile naming, and tactile object matching were rapid and accurate with the exception that he scored 2 of 5 with the left side. Motor-evoked potential monitoring was not performed.

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) was performed with a GE Medical Systems (Milwaukee, Wisconsin) 1.5-T Signa EchoSpeed Horizon instrument. An unenhanced, sagittal, T1-weighted spin-echo localizer, a coronal fluid-attenuated inversion recovery sequence, and a single-shot, spin-echo, echo-planar diffusion-weighted technique with gradient strengths corresponding to b values (diffusion sensitivities) of 0 and 1000 s/mm^2 were used. Also, a high-resolution, 3-dimensional spoiled gradient-echo scan (repetition time, 11 000 milliseconds; inversion time, 600 milliseconds; echo time, 4 milliseconds; matrix, 256 × 192; field of view, 24 cm; section thickness, 3 mm with no gap between sections; 60 sections; in-plane resolution, 0.94 mm) was acquired for coregistration with functional activation of MRIs.

FUNCTIONAL MRI

Blood oxygen level–dependent contrast images were acquired using a dynamic 2-dimensional single-shot spiral sequence.^{12,13} Twenty-three contiguous 5-mm slices were made (repetition time, 3000 milliseconds; echo time, 40 milliseconds; flip angle, 88°; field of view, 24 cm; matrix, 64 × 64) in oblique planes covering the whole brain. During fMRI, the patient performed structured finger tapping with either hand consisting of 3 alternating task and rest periods of 30 seconds, each requiring that he appose fingers 2 through 5 to the thumb in a specified order (3-5-2-4-2-3-2) at a rate of approximately 3 Hz for each hand while being monitored to ensure compliance.

The fMRI data were processed with SPM99b software (Wellcome Department of Imaging Neuroscience, London, England). Each image volume was smoothed by a kernel twice the voxel size, realigned using a 6-parameter rigid-body transformation to correct for head motion, and normalized to standard Montreal Neurologic Institute space using 12 linear 3-dimensional transformations with an echo-planar image template provided in the SPM program. Global effects were assessed by scaling to a common mean within each scan. Each voxel time series was subjected to temporal smoothing using a kernel that approximated the hemodynamic response function. These epoch-based data were modeled with boxcar design function convolved with a theoretical hemodynamic response function. Voxel-based multiple regression was used and statistical parametric maps were constructed for each condition, thresh-

olded at $P < .001$. Using gaussian theory, a cluster was considered to be activated if $P < .05$, based on peak T score and if the spatial extent was corrected for multiple, non-independent comparisons.

STRUCTURAL MRI

The anatomical images of the brain (**Figure 1**) showed a remote, 4-mm lacunar infarction in the posterior limb of his right internal capsule adjacent to the thalamus. Coronal fluid-attenuated inversion recovery images revealed high signal caudally into the corticospinal tract. As expected from a stroke 20 months prior to scanning, the diffusion-weighted images (not shown) were normal, indicating no acute/subacute infarctions.¹⁴

CORROBORATION OF FINGER DEXTERITY

Professional colleagues reported that both before and following the stroke the patient seldom used sheet music but learned by listening and practicing. Two years after his stroke, in their opinion, his performances, which typically included segments from many musical scores, were integrated seamlessly. They reported that chords, harmonic progressions, phrasing endurance, speed, timing, and play with ensemble dynamics were no different from prestroke performance.

fMRI DURING STRUCTURED TAPPING

Structured tapping with either hand activated the right cerebellum, left thalamus, left parietal, bilateral dorso-lateral prefrontal, and left supplemental motor areas (**Figure 2**). Right-finger tapping activated the left putamen and left sensorimotor cortex in addition to areas common in right-finger tapping. Left-finger tapping additionally activated the left cerebellum, left precentral gyrus, right putamen, and right parietal cortex.

COMMENT

We conclude that the patterns of activation relate to task performance and that they are not similar to subjects engaged in simpler tasks such as finger opposition. We cannot conclude that there is a change from a baseline because we have no baseline with which to compare performance. We speculate about these issues in the text. In normal subjects, a number of cortical regions are involved in sequential movements. Dominant left hemisphere areas control fine motor skills,¹⁵ including finger tapping¹⁶ and writing.¹⁷ The left parietal cortex is important for directing attention during planned motor activities.¹⁸ In a typical instance, some regional activity can be expected during rapid sequential motor tasks. However, in stroke patients, recovered hand movement generally has been associated with greater bilateral activation,¹⁹ particularly in the contralateral cerebellum.²⁰ Even though our patient ignored his left hand to play proficiently, he could carry out a serial tapping task with either hand. Thus, to comply with task demands, he recovered function of the affected hand.^{8,21-23} With structured tap-

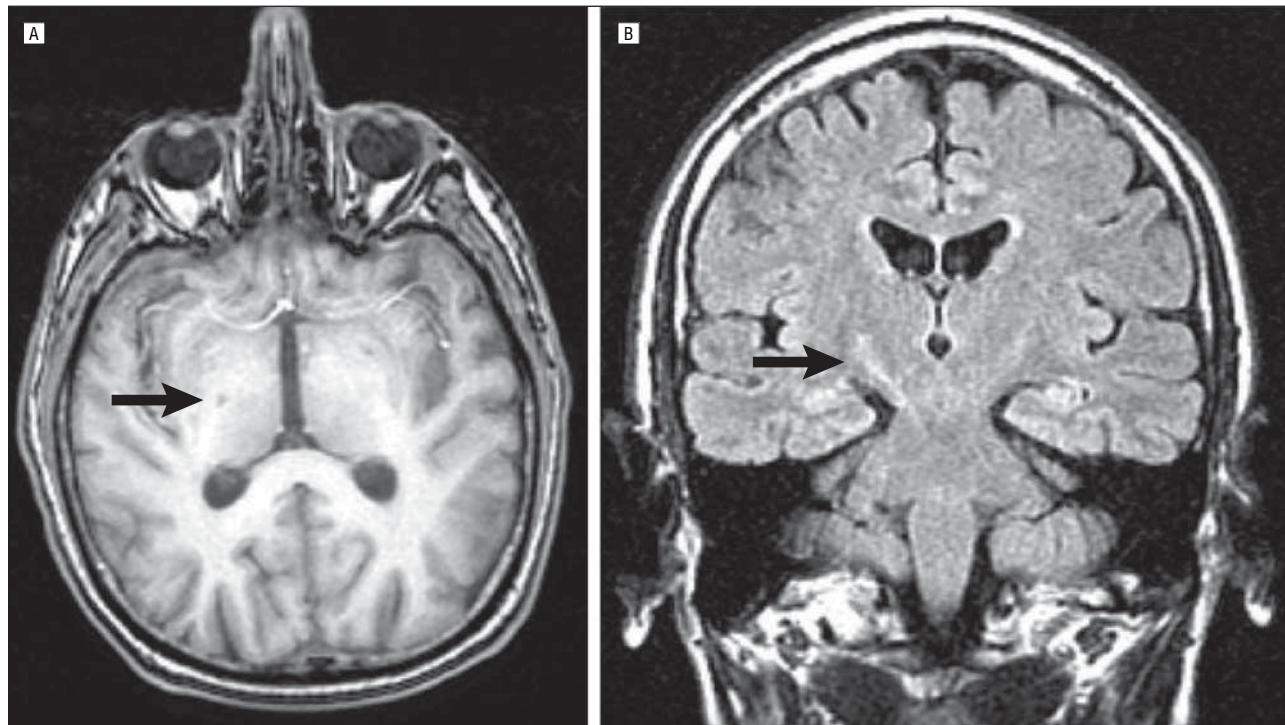


Figure 1. Three-dimensional spoiled gradient-recalled magnetic resonance images shown in radiological convention (right is on the left). A, The axial view reveals a 4-mm hypointense lesion (arrow) in the posterior limb of the right internal capsule, adjacent to the right thalamus. B, The fluid-attenuated inversion recovery image depicts hyperintensity in this same area (arrow), extending inferiorly along the white matter tracts to the brainstem.

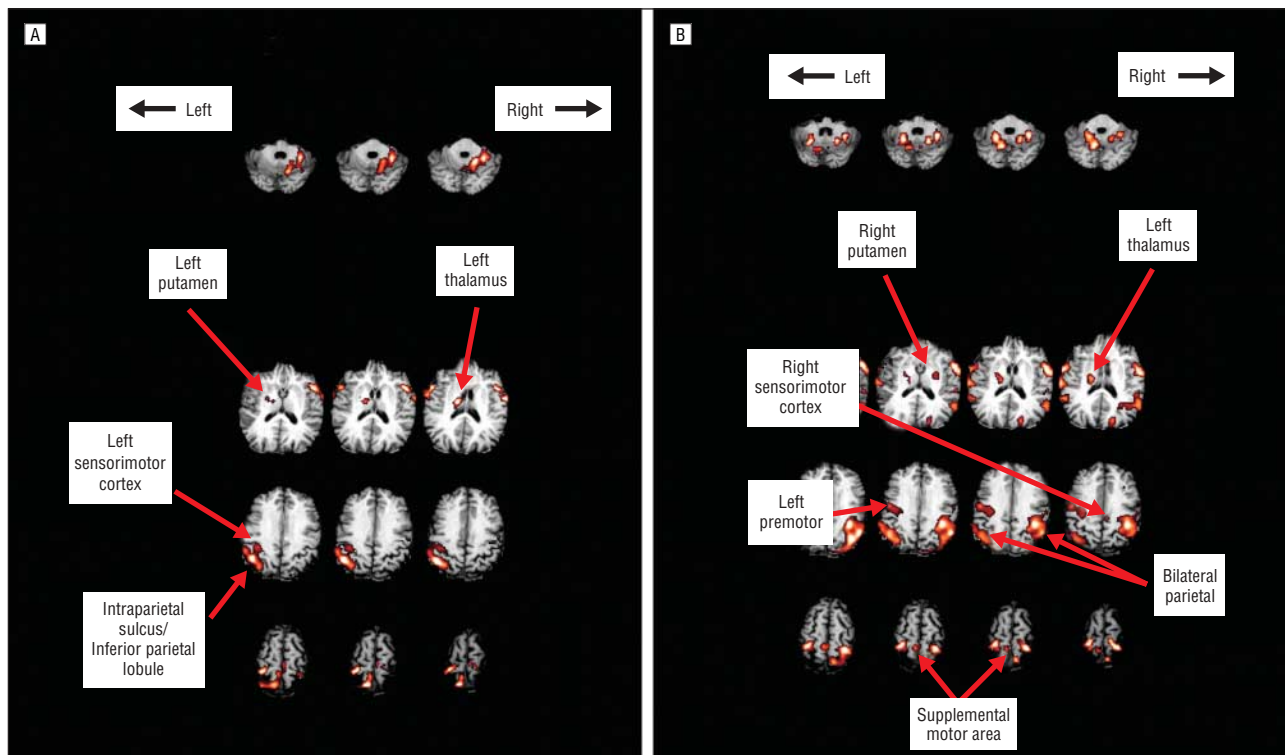


Figure 2. Functional magnetic resonance imaging activation during structured finger tapping with the right hand (A) and left hand (B). Statistical maps of significant clusters ($P < .05$, corrected for multiple comparisons) are overlaid on the patient's structural magnetic resonance image (right hemisphere is shown on the right).

ping with each hand independently, there was engagement of the ipsilateral cerebellum; contralateral sensorimotor, putamen, and parietal areas; and bilateral dorsal

prefrontal cortex. Left-hand tapping was distinguished from the unaffected right hand by bilateral cerebellar, parietal, and left premotor cortex activation.

An unanswered question is how left thalamic activation induces activation on the left side. In right-handed persons, the left premotor cortex is dominant for skilled motor acts in most individuals, and based on our patient's history and wife's observations, we conclude that he had left hemispheric dominance. His left premotor cortex activation relates to praxis for selecting the cortical module and/or suppressing the other cortical modules that are set into motion by the left premotor cortex. The additional task demands imposed by using his affected hand are the likely explanation for engagement of the left premotor cortex when unilateral left-hand actions were attempted. Movements of the affected side required a greater degree of activation in the left premotor cortex for 2 reasons: (1) a selection of the intact motor programs that work is more challenging and (2) unwanted right hemispheric activity is also likely to be more complex for the same reasons. With bilateral activation, it is much easier to ignore the affected hand because the brain is distracted by hand movements on the opposite side. Thus, one would expect less left premotor and left thalamic activation with a bilateral task, which is what we found.

We propose that recruitment of bilateral homologues by the affected hand is explained by compensation commonly observed in stroke recovery. This role is directed by the anterior supramarginal gyrus¹⁸ and anterior intraparietal sulcus. Moreover, the left hemisphere takes the dominant role regardless of which hand carries out the task. However, only during movement of the affected hand did the patient engage his left premotor cortex—an area proposed to mediate functional recovery of damaged primary motor connections. Similar findings have been reported by Weiller et al.⁸ We suggest that engagement of the left prefrontal area by this patient reflects motor attention in the selection and execution of a task carried out with the affected hand. To do so requires the recruitment of more areas than the same task carried out with the unaffected hand, even in this individual who previously used his left hand with great ease and whose motor speed and endurance remained higher than average. A recent study²⁴ reported that recovery in patients with right middle cerebral artery stroke is accompanied by a pattern of activation that reflects a change in attentional processing.

Serial tapping also activated the contralateral striatum, but only the left and not the right thalamus when either hand carried out the task. His performance by either hand was carried out via recruitment of a network that included the left thalamus and the striatum contralateral to the tapping hand as well as subcortical structures of the dominant hemisphere capable of forwarding motor commands to the hands via connections between cortical motor regions and the ipsilateral (thalamus and striatum) as well as the contralateral cerebellum.²⁵ In our subject, left thalamic activity could be explained by the increased need for allocating the resources necessary for left hemisphere compensation, as has been reported in other cases of excessive demand.²⁶

The structured finger tapping paradigm was chosen because we already had experience with this paradigm in a large study of stroke recovery using fMRI. Our pre-

liminary findings in the large study and some reports in the literature suggest that following stroke recovery, subjects might have increased activity in the cerebral hemisphere ipsilateral to the deficit (contralateral to the primary motor cortex) as well as in the contralateral cerebellum. Consequently, we predict that our professional musician, who had had a stroke, albeit not a cortical stroke, would have similar activation patterns. Thus, this study was based on our ongoing research in functional recovery after a stroke.

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Correspondence: James F. Toole, MD, Department of Neurology, Stroke Center, Wake Forest University School of Medicine, The Bowman Gray Campus, Medical Center Boulevard, Winston-Salem, NC 27157-1068 (jtoole@wfubmc.edu).

Author Contributions: *Study concept and design:* Toole, Burdette, and Absher. *Acquisition of data:* Absher. *Analysis and interpretation of data:* Toole, Flowers, Burdette, and Absher. *Drafting of the manuscript:* Toole, Flowers, Burdette, and Absher. *Critical revision of the manuscript for important intellectual content:* Flowers, Burdette, and Absher. *Statistical analysis:* Burdette and Absher. *Administrative, technical, and material support:* Toole, Burdette, and Absher. *Study supervision:* Toole and Flowers.

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