SHORT REPORT

Abnormal movement related potentials in patients with lesions of basal ganglia and anterior thalamus

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Abstract

Movement-related cortical potentials (MRCPs) were recorded from scalp electrodes during wrist flexion in 15 dystonic patients with bilateral (nine) or unilateral (six) circumscribed lesions in the striatum (eight), pallidum (six), or anterior thalamus (one). The results were compared with those of 10 age-matched healthy volunteers. The early (BP) and late (NS') MRCP components were assessed in terms of their gradients and distribution on the scalp in Cz, C3', and C4'. The gradients of both BP and NS' components were significantly flatter in the patients with bilateral lesions than in the control subjects. Also, the BP gradient was maximum at Cz, and the NS' component was contralaterally predominant in the control subjects but not in the patients. In patients with unilateral lesions, the gradients were flatter ($p < 0.05$) during movement of the dystonic wrist than during movement of the normal wrist. This difference was significant for BP and NS', regardless of the location of the electrodes. Also, the normal topographic predominance of BP at Cz and of contralateral NS' disappeared. The BP and NS' components of the MRCPs are thought to reflect preparatory activity in the supplementary motor area and the primary motor cortex before movement. Reduced BP and NS' gradients in patients with both bilateral

and unilateral lesions of the basal ganglia, which project towards the supplementary motor area, are consistent with this hypothesis. The bilateral nature of these reductions suggests that both the ipsilateral and the contralateral motor cortex are involved in the genesis of the MRCPs and that the dystonia in these patients is associated with impaired motor preparation.

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The negative slow potentials recorded from the human scalp before and after initiation of voluntary movements are referred to as movement-related cortical potentials (MRCPs).^{1,2} Shibasaki *et al*³ have termed the two main premotor components of MRCPs BP and NS'. It has been suggested that BP and NS' arise from motor cortical structures, particularly the supplementary motor area and primary motor cortex.^{4,5} Anatomical studies have shown that the pallidal output is directed from the thalamus to the supplementary motor area and, possibly, to the premotor cortex.⁶ Conversely, the supplementary motor area provides an input into the pallidum via the striatum, thus forming an anatomical loop between motor cortical areas and basal ganglia.⁷ MRCPs might thus reflect the activity of this motor loop. Abnormal MRCPs have effectively been described in Parkinson's disease,⁸ and we found restoration of their amplitude during chronic treatment with levodopa.⁹ Here, we recorded MRCPs in nine dystonic patients with bilateral lesions and six patients with a unilateral lesion of basal ganglia or anterior thalamus.

Subjects and methods

PATIENTS

Fifteen patients with lesions in the basal ganglia and thalamus were studied after obtaining their informed consent. There were six women and nine men aged between 21 and 51 (mean 30.7 (SD 9.02)) years and they were all right handed. Table 1 shows their main characteristics at the time of the electrophysiological test. All the patients had a dystonia (generalised or hemidystonia) and were free of treatment at the time of examination.

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Table 1 Clinical features of the patients

Patient	Age at study	Aetiology	Topography of lesion by MRI
Patients with bilateral lesions:			
B1	21/M	Encephalitis	Pallidum
B2	22/M	Post-hypoxia	Pallidum
B3	24/M	Post-hypoxia	Pallidum
B4	26/M	Post-hypoxia	Pallidum
B5	33/F	Vascular	Putamen and left caudate
B6	29/M	Birth anoxia	Putamen
B7	51/M	Encephalitis	Putamen
B8	24/M	Birth anoxia	Anterior thalamus
B9	25/F	Meningitis	Putamen
Patients with unilateral lesions:			
U10	45/F	Cranial trauma	Right putamen
U11	28/M	Birth anoxia	Right putamen
U12	42/M	Cranial trauma	Right putamen
U13	27/F	Cranial trauma	Right pallidum
U14	27/F	Vascular	Right pallidum
U15	41/F	Vascular	Right lenticulocaudate

B = bilateral; U = unilateral

Figure (A) Examples of movement-related cortical potentials (MRCPs) recorded in a healthy subject (CT2) and in patients with bilateral lesions of the pallidum (B2) or putamen (B6). The scalp electrodes were located at C4', Cz, and C3'. Baseline was measured by averaging the first 500 ms and latencies were measured relative to the baseline with reference to the onset of the EMG recording (point zero). BP is the early component of the shift and NS' is the late component. The maximum of NS' is N1, before EMG onset. Regression lines were drawn to determine the gradient of the two components. (B) Examples of MRCPs in patients (U10 and U12) with unilateral lesions of the putamen; on the upper part of the figure wrist flexion of the right (normal) side; on the lower part of the figure left (dystonic) side. Both the BP and NS' gradients were flattened.

Well circumscribed lesions of the basal ganglia were confirmed by MRI. There were nine patients with bilateral lesions and six with unilateral lesions (table 1). The bilateral lesions were pallidal in four patients, striatal in four, and in the anterior thalamus in one. All the unilateral lesions were located in the right hemisphere—four in the striatum and two in the pallidum.

CONTROLS

Ten age-matched right-handed healthy volunteers were chosen from the hospital personnel (six women and four men aged from 23 to 47 (mean 31.3 (SD 7.4)) years. Neurological examination and a CT scan of the head were normal.

RECORDING

During the recording session the subjects lay comfortably on a bed with their study forearm maintained in a wedge. They were asked to make self-paced, brisk, phasic movements of the wrist, roughly every 5 seconds. The subjects were instructed to fix a point on a screen in front of them, to avoid blinking, and not to count during the interval between movements. Two hundred movements were recorded during each session. The most strongly impaired hand was tested in the patients with bilateral lesions, and both hands were tested in the patients with unilateral lesions. The recording of the healthy volunteers was done during movement of the right wrist.

The surface electromyogram (EMG) was recorded from the flexor carpi ulnaris and amplified within frequencies of 100–3000 Hz. The onset of the EMG burst triggered data collection by a computer assisted system similar to that described by Barrett *et al.*¹⁰ EEG potentials preceding self-paced wrist flexions were averaged on line by an evoked potential apparatus (Basis signal averager, OTE) from three scalp electrode positions (Cz, C3', and C4'—1 cm anterior to C3 and C4 of the 10/20 system). The filter band pass was 0.03 Hz–1.6 kHz. Scalp muscle activity and blink artefacts were excluded by a rejection system that automatically discounts potentials greater than ± 0.1 mV. The EEG was averaged from 2.5 seconds before to 2.5 seconds after the upstroke of the EMG.

To measure the amplitude and velocity of the movement, a wedge hinge was placed coaxial to the wrist joint. The hinge contained a potentiometer that allowed the wrist angle to be measured. Angular velocity was measured with an electronic differentiator.

MEASUREMENTS

The measurements were done by two different investigators who were not informed of the clinical state of the subjects. Baseline was determined by averaging the recording from 2.5 seconds to 2.0 seconds before EMG onset in each channel. The gradients of the two premovement MRCP components (figure) were obtained by fitting a linear regression line between selected points. Onset of BP and peak negativity before EMG onset (N1) were first determined visually. The gradient of the early component was fitted by points on the shift between BP onset and 500 ms later, whereas that of the late component was fitted with points located on the shift between N1 and 500 ms earlier. Onset of NS' was determined on the shift as the intersection of the two regression lines. The figure gives examples.

STATISTICAL ANALYSIS

The significance of differences between the control subjects and the patients was determined by Student's *t* test. Differences between recordings over the electrodes of the ipsilateral and contralateral sides were compared by two-way analysis of variance. This was also done for recordings during right or left wrist flexions in the patients with unilateral lesions. Correlations between the movement kinematics and the gradients of the MRCP components were sought by linear regression analysis.

Results

Patients with bilateral lesions of the basal ganglia

The figure (A) shows an example of MRCPs recorded in a control subject (CT2), a patient with bilateral lesions of the pallidum (B2), and a patient with lesions of the putamen (B6). The latencies of the two main premotor components (BP and NS') did not differ between the patients and the control subjects. By contrast, the gradient of BP was flatter on both sides in the patients (mean 1.32 (SD 0.94) $\mu\text{V/s}$ at Cz) than in the control subjects (mean: -3.3 (SD 1.3) $\mu\text{V/s}$ at Cz) ($p < 0.01$). The gradient of NS' was also flatter (-3.4 (SD 1) $\mu\text{V/s}$ at the contralateral hand motor area) in the patients than in the control subjects (-8.4 (SD 1.8) $\mu\text{V/s}$) ($p < 0.001$) (table 2).

Changes were also noted in the MRCP topography over the scalp. In the control subjects the BP gradient was significantly greater at Cz ($p < 0.01$) and showed a bilateral symmetrical distribution at C3' and C4'. NS' was maximum at C3' for a movement of the right wrist. Its mean gradient (-8.44 (SD 1.81) $\mu\text{V/s}$) was significantly steeper ($p < 0.001$) than at C4' (-5.16 (SD 1.51) $\mu\text{V/s}$). In the patients with bilateral lesions, the BP gradient at Cz was not significantly different from that at other electrode positions. The NS' gradient at the contralateral hand motor area was not steeper than in the ipsilateral side.

Concerning the movement kinematics (table 2), the velocity of wrist movement in the patients with bilateral lesions was not reduced by more than 74% (range 90 to 220 degrees/s) relative to the control values. There was no correlation, in either patients or controls, between the velocity and gradients of the MRCPs, either for BP or for NS'.

PATIENTS WITH BILATERAL LESIONS OF THE THALAMUS

Patient B8, who had lesions in the anterior thalamus, showed a pronounced reduction in the gradients of both BP and NS' relative to the control subjects.

PATIENTS WITH UNILATERAL LESION OF THE BASAL GANGLIA

The figure (B) shows an example of the MRCPs for a movement of the left (dystonic) side in a patient with a limited lesion of the right putamen: scalp recordings of the BP and NS' gradients over the scalp were significantly flatter than during a movement of the unaffected side (BP $p < 0.01$, NS' $p < 0.05$). The gradients were also flatter ($p < 0.05$ for both BP and NS') relative to those in the control subjects (table 2). During the movement of the dystonic wrist, the gradient was flatter in both ipsilateral and contralateral recordings.

The normal topographic predominance of BP and NS' disappeared during movement of the normal or dystonic wrist. BP was therefore no longer predominant at Cz, and NS' was no longer predominant on the side contralateral to the movement. BP was not maximum at Cz for either right or left wrist movement. During movement of the right (normal) wrist, BP was predominant at C3' (contralateral normal hemisphere) by comparison with Cz and C4' (ipsilateral damaged hemisphere) ($F 13.47$, $df 2/10$, $p < 0.001$). There was no effect of electrode position on the BP gradient before left (dystonic) wrist flexion.

NS' DISTRIBUTION

Comparison of NS' amplitudes in C3', Cz, and C4' by ANOVA showed no significant differences between these electrode locations, whatever the side of the movement.

PARAMETERS OF MOVEMENT

The amplitude of wrist flexions did not differ between the right (dystonic) or a left (normal) sides of movement (table 2). The velocity was, however, significantly lower during movement of the affected side (200.8 (SD 29.7) degrees/s) than the normal side (323.3 (SD 38.8) degrees/s) ($p < 0.01$). No correlation was found between the velocity of movement and the gradient of BP or NS', whatever the side of the movement.

Table 2 Kinematic parameters and MRCPs

Patients	Kinematic		BP at Cz		NS' at CHM	
	Angulation (degrees/s)	Velocity (degrees/s)	Onset ((-) ms)	Slope ((-) $\mu\text{V/s}$)	Onset ((-) ms)	Slope ((-) $\mu\text{V/s}$)
Bilateral dystonia (mean (SD))	85 (16)	165 (50)	1546 (320)	1.32 (0.94)	864 (194)	3.41 (1.00)
Controls (mean (SD))	104 (11.09)	346 (33)	1562 (198)	3.28 (1.28)	840 (149)	8.41 (1.81)
Bilateral <i>v</i> controls ($p \leq$)	0.01	0.001	NS	0.01	NS	0.001
Unilateral dystonia, dystonic side (mean (SD))	100 (6.32)	196 (28.7)	1309 (168.5)	1.99 (1.06)	826 (188.7)	6.32 (3.87)
Unilateral dystonia, normal side (mean (SD))	105 (5.47)	355 (17.6)	1150 (202.7)	4.11 (1.16)	740.6 (98.8)	10.87 (4.18)
Normal <i>v</i> dystonic ($p \leq$)	NS	0.001	NS	0.01	NS	0.05

CHM = contralateral hand motor area.

Discussion

Relative to the healthy control values, both the BP and NS' gradients were flatter on both sides in the patients with bilateral lesions of the basal ganglia, and before movement of the impaired side in patients with unilateral lesions. All these patients had circumscribed ischaemic lesions of the pallidum, putamen, caudate nucleus, or anterior thalamus. These features are consistent with the involvement of basal ganglia and anterior thalamus in principal neuronal motor circuits,¹¹ the "complex loop" (prefrontal cortex, caudate nucleus, pallidum and substantia nigra, ventral anterior thalamus, prefrontal cortex), and the "motor" loop (premotor and sensory-motor cortex, putamen, pallidum, and substantia nigra, ventrolateral thalamus, premotor and sensory-cortex). As MRCPs are thought to originate from both the primary motor cortex and the supplementary motor area^{12,13} their decrease could reflect lower activity of motor cortical structures due to lesions in the basal ganglia. Failure of cortical activation of patients with Parkinson's disease and those with lesions of subcortical structures, particularly of the basal ganglia, has already been reported.¹⁴⁻¹⁶ These reports are in agreement with the decrease in MRCPs found here.

As well as the flattening of the gradients relative to those in the healthy control subjects, a change of the topographic distribution and a bilateral decrease in the MRCPs was noted during movement of the impaired side in the patients with unilateral lesions. As surface recording of the MRCPs probably reflects activities of both the right and the left motor cortex before voluntary movement,¹⁷ a large unilateral decrease in the activity of one hemisphere could produce a decrease in both right and left MRCPs recorded on the scalp. The activity of motor cortex structures could also be bilaterally reduced, however, in patients with unilateral lesions of the basal ganglia. Indeed, both bilateral supplementary motor areas are activated before unilateral, spontaneous, purposeful movement, as shown by subdural MRCP recordings^{12,13} and cerebral blood flow.¹⁸

As MRCPs probably reflect motor preparation before ballistic self-paced movements,¹⁹ our results could be due to an impairment of motor preparation after lesions of the basal ganglia. Various motor disorders have been described after such lesions.²⁰ Parkinson's disease is another condition in which there are elective lesions of these structures. Although an earlier study of MRCPs in Parkinson's disease gave conflicting results, Dick *et al.*^{18,21} showed that the earlier component of MRCPs was clearly reduced in patients with Parkinson's disease. In the early stages of Parkinson's disease, changes in MRCPs were limited to the BP component but in later stages the two premotor components were altered.⁹ Furthermore, there was a relation between amplitude of MRCPs and motor Parkinsonian scores.²² The patients we studied are dystonic and, as bradykinesia is seen

in Parkinson's disease, the pathophysiology of dystonic movement remains unclear. Although the movement of our patients were slower than in control subjects, the velocity was never less than 26% of normal and this was not sufficient to affect the MRCP gradients, which have been noted to be affected for a reduction of more than 90% of the velocity of movement.²¹ Also, there was no positive linear correlation between velocity and MRCP gradients. This suggests that the impaired motor control in dystonic subjects does not affect the velocity directly, but rather other parameters of motor programming, as has been suggested by peripheral recordings.²³ One of the involved parameters could be the increasing amplitude of muscular potentials at the onset of the muscular burst. Thus Hallett and Khoshbin²⁴ hypothesised that the basal ganglia are concerned with the grading of movement amplitudes by inappropriate energising of muscles.

Our results suggest that dystonic movements may be associated with a decrease in motor cortex activity due to a disruption of the striato-pallido-thalamo-cortical loop by a vascular lesion. Although MRCP flattening after lesions of the basal ganglia raises the problem of cortical or subcortical origin of its components, this study provides new insights concerning the relation between lesions of the basal ganglia and genesis of dystonia.

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- Kornhuber HH, Deecke L. Hirnpotentialänderungen bei Willkurbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente potentials. *Pflügers Arch* 1965;284:1-17.
- Vaughan Jr HG, Costa LD, Ritter W. Topography of the human motor potential. *Electroencephalogr Clin Neurophysiol* 1968;25:1-10.
- Shibasaki H, Barrett G, Halliday E, Halliday AM. Components of the movement-related cortical potentials and their scalp topography. *Electroencephalogr Clin Neurophysiol* 1980;49:213-26.
- Deecke L, Kornhuber HH. An electrical sign of participation of the mesial "supplementary" motor cortex in human voluntary finger movement. *Brain Res* 1978;159:473-6.
- Deecke L. Bereitschaftspotential as an indicator of movement preparation in supplementary motor area and motor cortex. In: Bock G, O'Connor M, Marsh J, eds. *Motor areas of the cerebral cortex*. Chichester: John Wiley, 1986:231-50. (Ciba Foundation Symposium 132.)
- Schell GR, Strick PL. The origin of thalamus inputs to the arcuate premotor and supplementary motor areas. *J Neurosci* 1984;4:539-60.
- Künzle H. An autoradiographic analysis of the efferent connections for premotor and adjacent prefrontal regions (areas 6 and 9) in Macaca fascicularis. *Brain Behav Evol* 1978;15:185-234.
- Dick JPR, Rothwell JC, Day BL, *et al.* The Bereitschaftspotential is abnormal in Parkinson's disease. *Brain* 1989;112:233-44.
- Fève AP, Bathien N, Rondot P. Chronic administration of L dopa affects the movement-related cortical potentials in patients with Parkinson's disease. *Clin Neuropharmacol* 1992;15:100-8.
- Barret G, Shibasaki H, Neshige R. A computer assisted method for averaging movement-related cortical potentials with respect to EMG onset. *Electroencephalogr Clin Neurophysiol* 1985;60:276-81.
- DeLong MR, Georgopoulos AP, Crutcher MD. Cortico-basal ganglia relations and coding of motor performance. *Exp Brain Res* 1983;7:158-68.
- Neshige R, Lüders H, Shibasaki H. Recording of movement-related potentials from scalp and cortex in man. *Brain* 1988;111:719-36.

- 13 Ikeda A, Lüders H, Burgess RC, Shibasaki H. Movement-related potentials recorded from supplementary motor area and primary motor area. Role of supplementary motor area in voluntary movements. *Brain* 1992;115: 1017-43.
- 14 Leenders KL, Palmer AJ, Quinn N, *et al.* Decrease metabolism in patients with Parkinson's disease measured with PET. *J Neurol Neurosurg Psychiatry* 1986;49: 853-60.
- 15 Wolfson LJ, Leenders KL, Brown LL, Jones T. Alterations of regional cerebral blood flow and oxygen metabolism in Parkinson's disease. *Neurology* 1985;35: 1399-405.
- 16 Deecke L, Englitz HG, Kornhuber HH, Schmitt G. Cerebral potentials preceding voluntary movement in patients with bilateral or unilateral Parkinson's akinesia. In: Desmedt JE, ed. *Attention voluntary contraction and event-related cerebral potentials: Progress in Clinical Neurophysiology* 1977;1:151-63.
- 17 Arezzo J, Vaughan HG. Intra cortical sources and surface topography of the motor potential and somatosensory evoked potentials in the Monkey. In Kornhuber HH, Deecke L, eds.: *Progress in brain research vol 54; motivation, motor and sensory processes of the brain: Electrical potentials, behaviour and clinical use.* Amsterdam: Elsevier Science Publisher, 77-88.
- 18 Roland PE, Larsen B, Lassen NA, Shinoj E. Supplementary motor area and other cortical areas in organization of voluntary movements in man. *J Neurophysiol* 1980;43:118-36.
- 19 Libet B, Gleason CA, Wright EW, Pearl DK. Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). *Brain* 1983;106:623-42.
- 20 Fève AP, Fénelon G, Wallays C, Rémy P, Guillard A. Axial motor disturbances after hypoxic lesions of the globus pallidus. *Mov Disord* 1993;8:321-6.
- 21 Dick JPR, Cantello R, Buruma O, *et al.* The Bereitschaftspotential, L-Dopa and Parkinson's disease. *Electroencephalogr Clin Neurophysiol* 1987;66:263-74.
- 22 Fève AP, Bathien N, Rondot P. Evolution des potentiels corticaux liés au mouvement chez les patients parkinsoniens, avant et après traitement par la levodopa. *Rev EEG Neurophysiol Clin* 1991;21:105-19.
- 23 Van der Kamp W, Berardelli A, Rothwell JC, *et al.* Rapid elbow movements in patients with torsion dystonia. *J Neurol Neurosurg Psychiatry* 1989;52:1043-9.
- 24 Hallett M, Khoshbin S. A physiological mechanism of bradykinesia. *Brain* 1980;103:301-14.