Callosum and movement control: Case reports

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This article explores the role of directionality of callosal traffic (codified as handedness), based on personal clinical observations and a critical review of the literature. Based on this evidence, a technical definition of handedness is offered as opposed to the behavioral method in use until now. In the vast majority of right-handers neural and behavioral handedness match. The situation is the opposite in left-handers where two thirds of them are wired to be right-handers, causing the well-known heterogeneity seen in left-handed cohorts. The callosum-length proximity of the dominant side of the body to the command center in the major hemisphere is the source of its neurophysiological superiority compared to the nondominant side. Clinical syndromes in which the new scheme are manifested are reviewed, indicating the existence of an excitatory influence by the neuronal aggregate devoted to voluntary actions, housed in the major hemisphere, on their counterparts in the minor hemisphere. The latter is exclusively devoted to volitional movements occurring on the nondominant side. Thus, it is the directionality of callosal traffic that is responsible for cerebral asymmetries seen in the motor realm. [Neurol Res 2003; 25: 538–542]

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INTRODUCTION

There is a controversy concerning the role of the callosum in laterality of movement control in human1,2. At the center of the dispute are questions concerning the nature of interhemispheric traffic (whether it is excitatory, inhibitory, or both), whether interhemispheric connection is bilaterally symmetrical or asymmetrical, in motor and sensory realms. And, there is practically no data as to the meaning of handedness, beyond the obvious descriptive stage, as it relates to its neural underpinning. The fact that the neural aspect of the handedness has been entirely consumed under the so-called cerebral specialization of various faculties is merely exchanging one unknown with another without answering the question: What is the neural substrate for handedness as a human trait? The one-way callosal traffic theory finds the verifiable answer in the existence of a neuronal aggregate devoted to voluntary activity and divided between two hemispheres.

Evidence is provided that handedness is codification of the laterality of the controlling moiety of the aggregate just mentioned, accomplished through the callosum.

In this communication three brief vignettes are provided relative to the enquiries sketched above, followed by a discussion based on a comprehensive review of the relevant literature, arriving at a novel understanding of motor control in human.

CASE HISTORIES

Case 1

RY is a well-educated alcoholic right-handed man, 48 years of age. He was found in convulsion because of which he had fallen and sustained a closed head injury. Clinically, he was alert. He had a left spastic paresis, left ptosis, but no language deficit and no apraxia. He had bilateral Babinski, more impressive on the left, where the abdominal and cremastic reflexes were at abeyance. His CT and MRI of the brain depicted swelling and displacement of the left hemisphere and a subdural bleed involving the whole left side (accentuated at parietal region). No other lesion was present anywhere else (Figure 1). The patient improved completely over the next three weeks. Two subsequent MRIs have been normal.

Case 2

BL is 37 years of age, always left-handed. He completed high school with good grades. His immediate post-traumatic extradural hematoma, shown in Figure 2, was evacuated quickly on arrival to the hospital. Since then he has remained with a severe left-sided spastic hemiparesis affecting the upper limbs more than the lower and a left Babinski, but no speech abnormality. He remains with a seizure disorder, which is under good control. Two subsequent MRIs have been normal.

Case 3

DM was 75 years of age, right-handed, who suddenly lost control of his left side. His complete left spastic hemiplegia improved in the subsequent months but not his severe left sided neglect. Severe apraxia on the left was noted, which also remained unchanged. His first MRIs showed only a callosal infarction probably due to the involvement of the anterior cerebral artery on one side or its branches. He could not sit or walk straight, constantly leaning to the left, despite eventual good recovery of the strength of left arm and leg. His diffusion weighted MRI is shown in Figure 3.
THE 1-WAY CALLOSAL TRAFFIC THEORY

The three examples summarized above provide a panoramic view of the role of the callosum in motor control; Cases 1 and 2 are examples of well-documented laterality indexed ipsilateral cortical paresis in lesions affecting the major hemisphere, which includes those cases of Kernohan himself in which the laterality of the lesions could be determined (from the photographs in his paper, as there is no reference to handedness in the series he published), removing any doubt that the weakness is related to diaschitic functional disorder of the minor hemisphere manifested ipsilateral to the lesion. This paresis, which is sometimes permanent, has been a documented source of diagnostic confusion and professional and legal entanglement by those who take the doctrine of contralaterality of movement control (CMC) too literally, unaware of the modifications recently proposed to account for the semiology under discussion (see below). Case 2 is among those left-handers whose laterality is ostensible, as it is the case in 70% of left-handers and in 15% of the population at large.

Figure 1: Case RY. Unenhanced MRI, showing acute subdural hematoma on the left. The bleeding is more noticeable over the temporoparietal region. The swelling of the left hemisphere is denoted by the asymmetry of the lateral ventricles in the views shown.

Figure 2: Case BL. Unenhanced CT, March 31, 1996. A: Left extradural hematoma showing crowding of perimesencephalic cistern and swelling of the left hemisphere. B: CT, May 10, 1996 showing normal configuration and structural integrity of the midbrain.
a finding repeatedly shown in large clinical samples\textsuperscript{13,14} as well as in sophisticated technical investigations\textsuperscript{15–17} and Wada test\textsuperscript{18}. His lesion (traumatic left extradural bleeding) associated with ipsilateral weakness without any aphasia and apraxia indicates that his neural laterality remained unchanged despite a life-long practice against the dictates of nature; the same was recently documented with the use of fMRI in a large series of cases in which bilateral activation of both motor cortices was seen when moving the nondominant hand\textsuperscript{19} (and largely contralateral when moving the dominant; see below for explanation). The diaschitic paresis of Case 3 was profoundly disturbing as it was associated with severe lack of awareness and/or denial of the problem thus hampering rehabilitation efforts.

There are a number of clinical and daily life observations that necessitate a modification of the CMC doctrine. Cases 1–3 represent the following classical trilogy not to be skirted in any cohesive scheme of explaining laterality of movement control in humans:

1. The occurrences of apraxia (ipsilateral) and paresis (contralateral) to a cortical lesion affecting the major hemisphere.
2. The occurrence of weakness/apraxia of nondominant side when the callosum (Case 3) is damaged.
3. The ipsilateral weakness resulting from affectation of cells in the major motor cortex whose axons traverse the callosum, activating their neuronal counterparts within the minor hemisphere (Cases 1 and 2).

To the above may be added two other groups of observations that witness the same excitatory influence of the major moiety (of the neuronal aggregate devoted to voluntary movements) on the minor. First, the documented effect of nondominant limb activity in significantly reducing visual neglect seen in line bisecting and line crossing tests in patients with parietal lesions in minor hemisphere\textsuperscript{20,21}. The second is the carefully quantified spontaneous improvement seen in the limb ipsilateral to the major hemisphere as the healing of the initial insult to that hemisphere is reflected callosally in the improved functioning of the motor cortex of the minor hemisphere dedicated to the movements occurring on the nondominant side\textsuperscript{22–24} (i.e. ipsilateral to the lesion).

Given the above facts, it seems clear the cohesive influence carried from the major to the minor hemisphere, via the callosum, is excitatory as the delineated symptoms speak of its withdrawal. Withdrawal of a similar excitatory influence from the same region is now accepted as the reason behind Brun’s cerebellar ataxia contralateral to a frontal lesion, which too is accompanied by diminished blood flow in the affected hemisphere\textsuperscript{25}.

In real life, the quickest demonstration of the expected physiological consequence of the novel understanding (i.e. a delay on the nondominant side equal to interhemispheric transfer time (IHTT)) is the two-clicks heard when we snap fingers of both hands loudly and simultaneously, the first sound coming from the neurally dominant hand (Derakhshan, unpublished data). Musi-
cologists have had a name for this inability to hit two notes simultaneously with both hands (the melody lead of the right hand in piano players) for 160 years. The same is witnessed as the asymmetry in crossed uncrossed differential (CUD) in Poffenberger paradigm, the precedence of the dominant to the nondominant hand in simultaneously drawing a spiral, and in all of Kelso’s earlier investigations, all commensurable to IHTT. The same fact is reflected in the earlier onset of the activity in the frontal cortical neurons of the major hemisphere (compared to that in the minor) related to movements of the vocal cords, the diaphragms and the face, as it had been earlier demonstrated for the limbs, cortically and at the effector level, and in the fact that moving the nondominant hand entails bihemispheric activity witnessed in fMRI, PET and high resolution EEG studies. Further testimony is obtained from the fact that transcranial magnetic stimulation of the minor hemisphere affects the evoked motor/muscle potential on the nondominant side alone whereas stimulating the major hemisphere affects the same bilaterally. Thus, the laterality of the callosal delay, as a representation of one’s neural handedness, validates the claim that handedness is a reflection (behavioral codification) of the vectorial/directional nature of interhemispheric relationship in the realm of voluntary movements; subject to those exceptions representing the triumph of the human will in defying the mandates of nature, but only ostensibly (see above).

Why a pervasiveness phenomenon with such an overwhelming clinical and laboratory supports should remain undiscovered, ignored or misinterpreted (as a manifestation of the laziness of the minor hemisphere) for so long? Perhaps one answer is in the simplicity of CMC doctrine representing an approximation to the truth, as well as unjustified but natural original assumption of symmetry in callosal traffic. But as it was demonstrated above, the CMC doctrine, while approximating the truth, is not the whole truth as it leaves a host of other relevant observations unaccounted for (see below). Ultimately, the other reason is complete reliance on the Wada test as the gold standard in determining laterality of speech faculty, giving rise to such subjects as bilateral representation of speech (or other functions). Ignoring for now the fact that a test in which incidence of such bilateralism varies between 0.5% to 65% is not a reliable test, the 1-way callosal traffic theory makes the issue moot; because all movements are, in a significant anatomical sense, bilateral as they all represent activity in a bihemispherically distributed neuronal aggregate devoted to voluntary movements as delineated above and elsewhere, all movements being planned and initiated from the command center on the left (in right-handed subjects). Kristeva et al. documented invisible occurrences of EMG activity in the left Flexor indicis with unilateral right-sided movements on average 50 msec after the compound motor potentials on the dominant side, a figure commensurate with IHTT. Finally, having a restricted view of events (i.e. syndromes) that later turn out to have wider implications than at first thought, in this case amounting to the existence of a distributed control system with the command center as part of the same, may ‘perplex’ even the experts. The response of Marien et al. to these observations, which were based on a comprehensive review of the literature (concerning nine reports of right-sided weakness in left-handed patients with Marchiafava-Bignami disease, or after callosotomy), may serve as an example here. The respected authors totally ignored their own reported fact that all of their nine behaviorally right-handed patients with crossed aphasia exhibited apraxia and difficulty writing with their neurally nondominant right hands (as defined above; see their Tables 1 and 2). Thus, when it comes to handedness it is not the laterality (handedness) that counts the most; rather, it is the relationship of the two hands in the totality of performance (as revealed in a comprehensive examination at the bedside). This is because of the mirroring of objective reality existing outside within the brain, configured and clustered in two hemispheres in a manner assuring the unity of mind (command center) in the motor realm. Thus, the need for modification of CMC doctrine, as outlined above, stems from the fact that it ignores the unity we sense when we do things with both hands. The 1-way callosal traffic scheme, on the other hand, provides our experience with a verifiable alternative explanation, all other facts remaining the same.

REFERENCES
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