Laterality of Motor Control or Raised Intracranial Pressure? Physiology not Physics Aids Understanding the Emergence of Ipsilateral Pyramidal Signs in Neurosurgery

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Abstract- A substantial number of surgical operations for supratentorial lesions are performed for fear of raised intracranial pressure and subsequent herniation of the brain. In this article I will show that the abovementioned fear is based on an irrelevant physical theory regarding the intracranial pressure, i.e. the Monroe-Kelley doctrine, which is ignorant of the fact that we breathe with our major hemispheres, hence the danger of lesions affecting the major hemisphere, which is also the hemisphere of speech and consciousness. Based on physiological consequences of one-way callosal circuitry underpinning lateralities of motor and sensory control, I confirm the more recent findings in neurosurgical literature that intracranial operations should be limited to those instances in which a lesion is directly interfering with the normal functioning of the neighboring neural structures and not because of considerations regarding the presence of raised in intracranial pressure. Using as example the tragic case of Congresswoman Giffords, who is incongruent as to her behavioral and neural handedness (see text for explanation), I have shown that the decompressive craniectomy she underwent resulted in the removal viable neural tissue, depriving her of a better outcome in the functioning of her nondominant side of the body. The new insight into the role of the major hemisphere in breathing and consciousness deserve utmost consideration when evaluating patients with intracranial lesions. This may demand abandoning the current practice of prophylactic craniotomy.

Keywords: prophylactic craniotomy, increased intracranial pressure, motor control, handedness.

Introduction

There is substantial evidence that raised intracranial pressure, as determined in bedside settings, is irrelevant to the occurrence of clinical (i.e. ipsilateral paralysis) and pathological (transient herniation) findings seen in patients with supratentorial space occupying lesions or in those with traumatic brain injury (with or without edema). This article provides an alternative physiological explanation of ipsilateral paralysis, classically explained by transient herniation of the brain, based on directionality in callosal traffic, underpinning lateralities of sensory and motor control in humans. 1, 2 Although the advent of neuroimaging techniques in recent decades (e.g. CT and MRI scans) has diminished the need for a meticulous examination of patients in search for the presence of pyramidal signs ipsilateral to a supratentorial lesion, it is hoped that a better understanding of the physiological underpinning of those ominous “false localization signs” would have a bearing on abandoning the current practice of (unnecessary) craniotomies performed for averting the “life threatening” consequences of raised intracranial pressure in these circumstances (cerebral herniation, Kernohan notch).

Physics

According to the Monro-Kellie doctrine, a fully formed cranium is a rigid box in which an increase in the volume of any of its histological constituents will be accompanied by a decrease in the volume of the remaining components in order to avoid an increase of the intracranial pressure. At the same time, the doctrine specifies the formation of transtentorial herniation as a consequence of raised intracranial pressure, in turn giving raise to the notching of contralateral cerebral peduncle as it presses against tentorium cerebelli; causing hemiparesis ipsilateral to the space occupying lesion due to the Kernohan-Woltman phenomenon. This scenario, however, has many weaknesses the most glaring of which has been elucidated only recently. Thus, the occurrence of false localizing signs in Kernohan and Woltman’s classical study was limited to 17 of the 35 cases with supratentorial lesions (i.e. exacting half of those studied), despite the fact that all of them had the peduncular notching contralateral to the tumor. This fact alone reduces the status of the peduncular notching to that of an irrelevant artifact rather than being the “cause” of the ominous but “false” localizing signs (ipsilateral paralysis). 1, 2

It bears mentioning here that the therapeutic usefulness of decompressive craniectomy for relief of raised intracranial pressure has come under heavy criticism in recent times. 3, 4
Physiology

According to one-way callosal traffic circuitry, the abovementioned ipsilateral pyramidal findings are the result of transcallosal deafferentation of the minor hemisphere from the excitatory signals arising in the major hemispheres (i.e. diaschisis), underscoring the fact that all commands arise in the major hemisphere regardless of the laterality of the effectors intended for such commands. In addition to a plethora of clinical evidence supporting the above conclusion, the existence of a moiety within the plethora of clinical evidence supporting the above conclusion, the existence of a moiety within the major hemisphere which is devoted to the affairs occurring on the nondominant side of the body/space has been documented by Kooi et al and Baumer et al, respectively employing electro-encephalography (EEG) and transcranial magnetic stimulation techniques (TMS). Specifically, Kooi and colleagues described the initiation of “temporal transients” in the left hemisphere with transmission of those signals to the right hemisphere within 200-1000 milliseconds. According to Kooi et al, such transients were four times more likely to arise from the left hemisphere and spread to the right than the other way around. The above left/right ratio corresponds to that of the laterality of motor control at the society at large. Therefore, it is likely that the transients described by Kooi et al and Jaffe et al were representations of the more recently described respiratory cortical evoked potentials. The frequency at which these alpha transients occurred in Jaffe et al’s study (~ 20/minutes) is consistent with the above statement. In the same vain, the hazard ratio for sudden death attributed to respiratory arrest following stroke involving the major hemisphere was four times higher in right handers compared to those who were “ambidextrous” or left handed (HR, 0.96 vs 0.24). Kooi et al’s denial of a relationship between handedness and the laterality of the temporal lobe seizures is unwarranted since a large segment of those claiming left handedness or ambidexterity are wired as neural right handers (i.e. they are left hemispheric as to the laterality of motor control). In the TMS experiments conducted by Baumer et al, an interstimulus interval of up to 10 milliseconds between conditioning and test stimulus was need for the facilitating stimuli to the left hemisphere to reach the right hemisphere of the right handed participants studied. Lastly, the constant temporal association of paroxysms of petit mal seizures and apnea may be regarded as indicative of a common origination of both phenomena from the same hemisphere. It may therefore be concluded that the ratio of fifty percent reported in Kernohan and Woltman’s classical article (i.e. 17/35), reflected the fact that lesions of only one of the two hemispheres (not both) were associated with emergence of the ominous pyramidal signs ipsilateral to that hemisphere (i.e. the major hemisphere). Thus, the above-mentioned ratio may be viewed as the foot print of directionality of the excitatory signals in callosal traffic (i.e. from the major to the minor hemisphere), withdrawal of which resulted in the appearance of pyramidal signs ipsilateral to the major hemisphere, due to an interhemispheric diachisis affecting the minor hemisphere.

At this juncture the following questions arise:

1. Are there other circumstances (syndromes) indexed to the laterality of motor control (as delineated above) the occurrences of which bear similar numerical characteristics, i.e. a fifty percent or less probability of occurrence in lesions that are likely to be equally distributed between the two hemispheres?

2. Is the incidence of epilepsy resulting from supratentorial lesions always less than 50 percent?

The answer to both questions is in the affirmative. For example, in a study by Faught et al, describing de novo seizures among 123 patients with primary intracerebral hemorrhage, 25 percent developed seizures within five years after hospitalization (with lobar hemorrhage in 44 cases). The authors indicated that the predicted cumulative seizure incidence for their patients was 50% had all patients survived and followed for five years. In the data presented in this article seizures occurred in 23/44 patients with lobar intracerebral hemorrhage. This ratio is similar to the abovementioned ratio of 50% for emergence of “false localization signs” in Kernohan and Woltman series (see above). To repeat, the 50 percent (or fewer) rule for the incidence of epilepsy in supratentorial metastatic lesions, meningiomas and cavernous angiomas, signifies that only one half of the entire supratentorial cortical expanse is capable of generating seizures even if the lesions were bilateral in their distribution. Thus, given the equal likelihood of hemispheric involvement in these and similar lesions, it is likely that the anatomy sustaining the laterality of motor control provides the anatomical substrate for the abovementioned ratio; i.e. only one of the two hemispheres is capable of generating epilepsy, a finding that enjoys historical and experimental support. Thus, in an experiment involving ablation of both motor cortices in monkeys, Pribram et al documented the role of the left hemisphere in generating epileptiform potentials. In the latter study, however, the laterality of the lesion as the source of the observed epileptiform discharges escaped the authors’ attention. A similar attitude has been displayed by two other influential investigators. Roland et al and Tanji et al were both inattentive to the fact that bilateral cortical activation observed in their experiments occurred as their subjects moved their nondominant arms. Finally, the more recent demonstration of bi-hemispheric activation of the brain upon using the nondominant hand involved the employment of near infra-red spectroscopy (NIRS) in measuring regional circulation of the brain when performing maximum pinching exercises with the left hand and the electromyographic documentation of the precedence of muscular activity in the right hand compared to the left (by
53 milliseconds) when right handed participants engaged in bimanual simultaneous pinching exercises. In this connection, the fact that apnea is a constant companion of petit mal epilepsy bear remembering. The most naturalistic way of demonstrating this callosum-mediated asynchrony is the use of bimanual simultaneous drawing maneuver. In this test, the delay in moving the nondominant hand is reflected in the asymmetrical performance of the two hands when drawing a straight line or a box-shaped configuration. The lines drawn by the dominant hand are longer and straighter than those drawn by the nondominant because the latter is farther from the command center by a callosum-width, resulting in the degradation of the signal originating in the major hemisphere. Further, it has been shown that the numerical discrepancy between performances of the two hands remain unchanged despite days of practice.

The Eyes Have It

Another way of distinguishing the major from the minor hemisphere is to notice the deviation of the eyes toward the anesthetized (Wada test) or injured (e.g. supratentorial stroke) minor hemisphere, since an injury to the major hemisphere is not accompanied by conjugate eye deviation (CED) (Prevost sign); nor are the lesions affecting the minor hemisphere associated with the development of epilepsy. Retrospectively, the role of laterality of motor control in the genesis of CED was evident from the start. Thus, thirty six of the fifty one cases of CED reported by Prevost had supratentorial lesions of the right hemisphere at the autopsy. In addition, none of the remaining 15 cases with supratentorial strokes affecting the left hemisphere with conjugate deviation of the eyes to the left had language deficit arising from the newly acquired apoplexy (vascular event). The latter observation is consistent with the suggestion that the second group consisted of neurally left handed subjects regardless of their behavioral preference (i.e. they were all right hemispheric in their laterality of motor control). Significantly, it is among the second group of Prevost’s patients that the first description of a (cortical) internuclear ophthalmoplegia (Case 50), depicted by the author as follows: the eyes were deviated to the left, particularly the left eye. The diaschitic nature of this syndrome, known as the lone abducting eye and caused by temporary paralysis of the contralateral medial longitudinal bundle, has been commented upon elsewhere (Figure1).

Case in Point

According to publicly available information, Congresswoman Giffords was tragically shot in the head in January 8th, 2011 with a bullet entering into her left hemisphere above the eye brow and exiting posteriorly near the midline (probably traversing frontal and parietal lobes). Since, there has been no report indicating occurrence of epilepsy following the trauma. There are reports indicating that she was conscious on arrival to the hospital and that she carried out simple commands from the start. She began speaking sometime thereafter (most likely indicating an initial mutism) but has since participated in multiple speaking engagements and has shown normal comprehension of speech. She has remained with complete paralysis of the right arm and leg but is able to take steps and has fairly good balance when walking. Linguistically, her speech is slow and marked by semantic paraphasia (e.g. replacing “Sandy-Brook” for “Sandy Hook”). In this connection, it is important to note that expressive language disturbances in supratentorial lesions have no lateralization value since moving the tongue and lips require an orderly participation of both hemispheres regardless of the laterality of the command center.

In the case of Congresswoman Giffords, the most significant lateralizing sign was represented in the “shocking” hospital photos released in November of 2011, demonstrating the presence of a (cortical) internuclear ophthalmoplegia on the right side with the left eye completely deviated to the left but the right eye stopping at the middle (Figure 2). Following the trauma the patient has undergone three operations on the head: left “decompressive” craniotomy, right lateral canthotomy and left cranioplasty.

According to the clinical information provided above, Congresswoman Giffords’ is that of a crossed nonaphasia in an ostensible right hander; i.e. a person who is wired as a left hander with the command center in her right hemisphere, as revealed by the eye deviation towards the injured hemisphere as depicted in Figure 2. Similar cases have been described in the past, all remarkable for the preservation of comprehension and absence of apraxia in the limbs ipsilateral to the damaged hemisphere.

Conclusion

According to the observations recounted above, Congresswoman Giffords sustained an injury to her nondominant hemisphere and was never in danger of respiratory disturbances seen as a result of injury to the breathing hemisphere. The initial craniotomy performed for fear of an “impending herniation” was thus unnecessary and unjustified and probably has compromised chances of any recovery by removing useful brain tissue. So was the right lateral canthotomy, which seem to have been performed “looking for orbital bone fragments.” This perhaps was due to a misinterpretation of the unusual occurrence of cortical internuclear ophthalmoplegia seen in Figure 2.
Figure 1. Lone abducting eye in a truly right handed person. The right eye, with its intact motor connection to the left hemisphere, has been pulled to the right as a result of an imbalance created by the right-sided stroke (image on the right). The fibres going from the left cortex to the right lateral rectus find their way directly, without callosal participation, to brainstem nuclei on the right (middle image). The left eye which normally follows the right in such a situation becomes immobile because of the diaschisis affecting the pons as a result of the acute lesion affecting the right hemisphere. This may indicate a wider diaschitic paralysis of the left brainstem than that present in cases with conjugate deviation of the eyes to the left. Notice that in the case of Congresswoman Giffords, who is wired as a left hander, the laterality of events are in the reverse direction compared to those depicted above [adopted from CMAJ’s article, 2005].

Figure 2. Note the stoppage of the right eye at the middle with the left eye deviated to the left, i.e. presence of a cortical internuclear ophthalmoplegia (see the text for explanation).

References


[13] Derakhshan I. Bimanual simultaneous movements and hemispheric dominance: Timing of events reveals hard-


