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Vestibular caloric stimulation evokes phantom limb illusions in patients with paraplegia

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Study design: Prospective study.

Objectives: To determine the mechanisms of body illusions in paraplegia patients as compared with the amputee phantom phenomena.

Methods: A vestibular caloric stimulation was performed in 10 consecutive patients with complete section of the spinal cord. Perception of body, before and after stimulation, was classed as illusion of a normal body (lower limbs with normal morphological, postural and kinetic characteristics perceived as before spinal injury), normal phantom (overly vivid perception of all or part of the lower limbs), deformed phantom (perception of all or part of the limbs below the injury level as abnormal in shape, posture, movement or even number), or painful phantom.

Results: After vestibular caloric stimulation, nine out of 10 patients stated their perception of body segments below the injury level had changed to normal phantoms or to deformed phantoms (morphological, postural or kinetic changes). Among the four patients who initially had painful limbs, two stated the stimulation greatly relieved their pain.

Conclusion: The normal or deformed phantom evoked by vestibular stimulation would result from use of identity data or instantaneous data as is observed in amputees. Cerebral remapping following deafferentation could be the origin of the deformed phantoms. Illusions corresponding to phenomena perceived at the time of the accident corresponding to autobiographical engrammes do not appear to be evoked by vestibular stimulation, as is also the case in amputees.

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Introduction

Phantom limbs and body illusions below the spinal cord injury in paraplegic patients take on many forms, resulting from several mechanisms.[1,2] Certain body illusions, such as somatophrenia (exaggeration or imagination of body ills) and hemibody neglect in left-side brain injury patients, or phantom limbs in amputees, can be evoked, modified or abolished by vestibular stimulation.[3] We observed, apparently for the first time, that vestibular stimulation can also affect perception and representation of body segments below the level of spinal cord injury, changing their morphological, postural and kinetic characteristics.

Materials and methods

Ten consecutive patients (eight men, two women, mean age 34 years, age range 19–63 years) with complete section of the spinal cord (as confirmed by clinical presentation and absence of cortical response to somaesthetic evoked potentials) were included in the study after written informed consent. Spinal cord injury was due to trauma in nine cases and infection in one. Time since total deficit was 13.8 months (mean, range 2–75 months). Motor and sensitivity levels (ASIA\IMSOP score) are given in Table 1. The patients were asked to state their spontaneous perception of their lower body and to answer specific questions before and after vestibular caloric stimulation. Perceptions were classed as:

(1) illusion of a normal body (body segments at and below the spinal cord injury perceived with normal morphological, postural and kinetic characteristics as before spinal injury despite complete anaesthesia; these characteristics vary with current position and activity and produce a body perception identical to that which would be expected for such position or activity. For example, in the sitting position with no visual control, the legs are

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Table 1 Patient characteristics and main effects of vestibular stimulation

			Neurological level ASIA/IMSOP score					*Spontaneous corporal illusion and phantom*				
			motor		*sensitive*		*Time elapsed*	*Normal*	*Phantom*	*Phantom*	*Phantom*	*Stimulation*
No.	*Age*	*Gender*	*L*	*R*	*L*	*R*	*(months)*	*Body*	*Normal*	*Deformed*	*Pain*	*effects*
1	30	M	T6	T6	T6	T6	6	Yes	No	No	No	PN
2	55	M	T12	T12	T12	T12	5	No	No	Yes	Yes	PD PP↓
3	22	M	T8	T8	T8	T8	8	Yes	No	No	No	PN
4	63	F	T9	T9	T9	T9	7	Yes	No	No	Yes	PN PP↓
5	30	M	C6	C6	C7	C7	75	Yes	No	No	Yes	No
6	39	F	T6	T6	T6	T6	2	Yes	No	Yes	No	PN
7	19	M	T10	T10	T9	T12	28	Yes	No	No	Yes	PN
8	25	M	C6	C8	C8	C8	5	Yes	Yes	No	No	PD
9	23	M	C8	C8	C8	C8	1	Yes	No	Yes	No	PN
10	34	M	C5	C5	C5	C5	1	Yes	No	No	No	PN

PN: phantom normal. PD: phantom deformed. PP↓: phantom pain decrease

perceived as flexed even if the lower limbs were in the extended position);[4]
(2) normal phantom (overly vivid perception of all or part of the limbs below the injury level);[5]
(3) deformed phantom (perception of all or part of the limbs below the injury level as abnormal in shape, posture, movement or even number);[6]
(4) painful phantom.[7]

Some patients experienced several types of illusions or phantoms, usually in an intermittent fashion. Vestibular caloric stimulation was performed in the supine position, arms and legs extended and eyes blinded, by rapid infusion of 20 cm^3 saline solution at 20°C into the external auditory canal (cold stimulation). This stimulation was considered to be effective if it triggered nystagmus. By convention, stimulation was performed on the left side.

Results

The main characteristics of the study population and their perceptions before and after stimulation are presented in Table 1. Before stimulation, nine patients had an illusion of a normal body associated with a painful limb ($n = 3$) (one at injury level, and two below injury level), a normal phantom ($n = 1$) or a deformed phantom ($n = 1$). One patient spontaneously reported perceiving a deformed phantom with painful lesions. After vestibular caloric stimulation, nine out of 10 patients stated their perception of body segments below the injury level had changed to normal phantoms or to deformed phantoms (morphological, postural or kinetic changes). Only one patient did not report any change in perception; this was the patient who did not develop nystagmus or vertigo at vestibular stimulation. Among the four patients who initially had painful limbs, two stated the stimulation greatly relieved their pain.

Discussion

Vestibular stimulation can evoke phantoms below the injury level after complete section of the spinal cord. Several types of body representations can be distinguished. The body representation (neuromatrix) model proposed by Melzack[8] in amputees appears to be applicable to spinal cord injury patients. The neuromatrix collects and selects pertinent input from multimodal, mainly somatosensorial, afferents corresponding to the immediate body situation, and also from memorised engrammes (innate body engrammes, developmental body identity engrammes, post-developmental autobiographical engrammes). In routine situations or when certain basic input is missing or erroneous, the brain has to choose among the different engrammes to maintain internal coherence. This produces different types of illusions.

In spinal injury patients, the spontaneous illusion of a normal body (perception of a normal and/or neutral body) would suggest the brain has constructed a body schema based on memorised identity data, ie engrammes established during the first years of life. The normal or deformed phantom evoked by vestibular stimulation would result from use of the same identity data and instantaneous sensorial feedback data from changes in activity or status, as is observed in amputees. Cerebral remapping can be assumed to occur in amputees following deafferentation. This could be the origin of the deformed phantoms. Illusions corresponding to phenomena perceived at the time of the accident (car driving position, pedalling in bicyclists) corresponding to autobiographical engrammes do not appear to be evoked by vestibular stimulation, as is also the case in amputees.

We are currently examining spina bifida subjects with complete paraplegia using the same protocol in order to determine the relative roles of innate and identity engrammes, as also studied in amelic children.

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