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Report 2013: Tumors of the pineal region

Sensorimotor mapping of the human cerebellum during pineal region surgery

Cartographie des fonctions sensorimotrices cérébelleuses durant les chirurgies de la région pinéale

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ABSTRACT

Background. – The cerebellum is a fundamental structure of the central nervous system. However, in humans, its anatomo-functional organization and the processes through which this organization adapts in response to injuries remain widely unknown.
Methods. – Motor and somatosensory evoked potentials were used to map functional representations in the posterior cerebellum of patients with extra- and intracellebellar injuries. Extracerebellar patients had injuries outside the cerebellum (e.g. pineal region, quadrigeminal plate) while intracerebellar patients had injuries within the cerebellum. Data were collected in 20 extracerebellar patients for motor representations. Only preliminary data were gathered for somatosensory representations and intracerebellar patients.
Results. – In extracerebellar patients, electrical stimulation induced muscle contractions in the ipsilateral hemibody. These representations were somatotopically organized with large overlaps between the face and upper limb in the superior posterior cerebellum and the upper and lower limb in the inferior posterior cerebellum. Neck muscles were represented in the oculomotor vermis. In intracerebellar patients, preliminary data seem to indicate that motor plasticity is achieved by recruiting the contralesional (healthy) cerebellar hemisphere.
Conclusions. – Although still ongoing, this project could eventually lead to an improvement of the surgical treatment of patients with lesions of the posterior fossa, by improving our knowledge of cerebellar organization and the process of post-lesional plasticity.

Mots clés :
Neurochirurgie
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Fosse postérieure
Cervelet
Potentiels évoqués moteurs
Potentiels évoqués somesthésiques

RÉSUMÉ

Objectifs. – Le cervelet est une structure fondamentale du système nerveux central. Pourtant, chez l'homme, son organisation anatomofonctionnelle et les processus permettant à cette organisation de s'adapter en réponse à une atteinte neuronale restent mal connus.
Méthodes. – Les potentiels évoqués moteurs et somesthésiques ont été utilisés pour cartographier le cervelet postérieur de patients porteurs de lésions intracérébelleuses (touchant le cervelet lui-même) et extracérébelleuses (localisées hors du cervelet, par exemple au niveau de la glande pinéale). Une cartographie motrice a été obtenue chez 20 patients extracérébelleux. Seules des données préliminaires ont été collectées, à ce stade, pour le champ somatosensoriel et les patients intracérébelleux.
Résultats. – Chez les patients extracérébelleux, la stimulation électrique du cortex cérébelleux produit des contractions musculaires ipsilatérales. Ces contractions sont organisées de manière somatotopique avec de larges recouvrements entre la face et le bras dans la partie supérieure du cervelet postérieur et entre la jambe et le bras dans la partie inférieure du cervelet postérieur. Les muscles de la nuque sont représentés dans le vermis oculomoteur. Chez les patients intracérébelleux, des données préliminaires indiquent qu'une certaine plasticité motrice peut être obtenue à travers le recrutement de l'hémisphère cérébelleux contralésionnel sain.

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Conclusions. – Même s'il est en cours de réalisation, il apparaît que ce projet pourrait, en améliorant notre connaissance de l'organisation cérébelleuse et du processus de plasticité post-lésionnelle, conduire à une meilleure prise en charge chirurgicale des patients porteurs de tumeurs et malformations de la fosse postérieure.

1. Introduction

The cerebellum is located in the inferior posterior portion of the head, directly dorsal to the pons, and inferior to the occipital lobe. Its cytoarchitecture is consistently regular and highly uniform across the entire cortex (for reviews, [1,2]). Anatomically, it is heavily connected with many other areas of the brain at the cortical and subcortical levels. Although, it represents roughly 10% of the total brain volume, it contains almost 50% of all neurons. Functionally, the dominant view of cerebellar function over the last century has been that this structure is mainly concerned with the coordination and control of motor activity [3–5], although recent evidence exists that computations carried out within the cerebellum are also important for non-motor functions [6–8].

At a clinical level, cerebellar tumors and malformations are quite frequent in both adults and children [9,10]. Surgery represents a major therapeutic approach. The problem is then for the surgeon to remove the tumor or resect the malformation without inducing post-operative deficits. Having a precise knowledge of the organization and plasticity of cerebellar sensorimotor organization could be of help in order to achieve this goal. Unfortunately, to date, this knowledge remains lacking. After decades of intense research, there is still no consensus on how the cerebellum is organized [11]. In light of this observation, we decided to investigate the sensorimotor organization of the cerebellum in patients undergoing surgery of the posterior fossa. Because these types of surgeries do not permit access to the anterior cerebellum, the present investigation was limited to the posterior cerebellum. To achieve our goal, we used both motor and somatosensory evoked potentials. Two populations of patients were considered. The extracerebellar group involved patients with damage outside the cerebellum (e.g. in the pineal region, quadrigeminal plate). The intracerebellar group involved patients with cerebellar damage. To date, we have only completed one study that aimed to investigate motor organization in extracerebellar patients [12]. Only preliminary data have been obtained and processed for sensory organization in extracerebellar patients and sensorimotor plasticity in intracerebellar patients.

2. Patients and methods

Patients older than 10 years of age were recruited from the neurosurgical department of the neurological hospital in Lyon. Prior to surgery, they were informed about the surgical procedure by the senior surgeon (C.M.) and gave their formal consent (for minors, consent was obtained from the parents) to participate in the study. The protocol was approved by the local ethics committee (CPP, Lyon Sud-Est IV, centre Léon-Berard, Lyon) and sponsored by CNRS.

2.1. Sensorimotor mapping in extracerebellar patients

Detailed data related to motor mapping in extracerebellar patients have been reported in detail in a previous paper [12]. In brief, 20 patients with extracerebellar lesions were recruited. The mapping was performed before the beginning of the surgical resection. Following opening of the bone flap and the dura, a bipolar electrode with 5 mm spaced tips delivering a square biphasic current was placed on the cortex of the patients (pulse frequency 60 Hz) (Fig. 1a). Direct electrical stimulation was delivered using standard increasing intensities (2, 5, 10 mA) and a fixed duration (approximately 2 s). Duration of the stimulation was defined by the surgeon through counting ('one, two'). When a movement was found, the site was defined as responsive and no additional stimulation was performed. When no response was found at 10 mA, the site was considered unresponsive. Except for two patients operated in a ventral position, all surgery was performed in a seated position using either an infratentorial supracerebellar or occipital-transtentorial approach [13,14]. During stimulation, electromyographic activity (EMG) was collected bilaterally in 10 muscles covering the face/mouth (zygomaticus/orbicularis oris), neck (sternocleidomastoid), elbow (biceps, triceps), wrist (extensor digitorum communis, flexor carpi radialis), hand (thenar, hypothenar) and foot (tibialis anterior, gastrocnemius). Disposable surface Ag/AgCl electrodes were used to record EMG signals. During surgery, these signals were differentially amplified by a factor of 1,000–20,000 to produce data

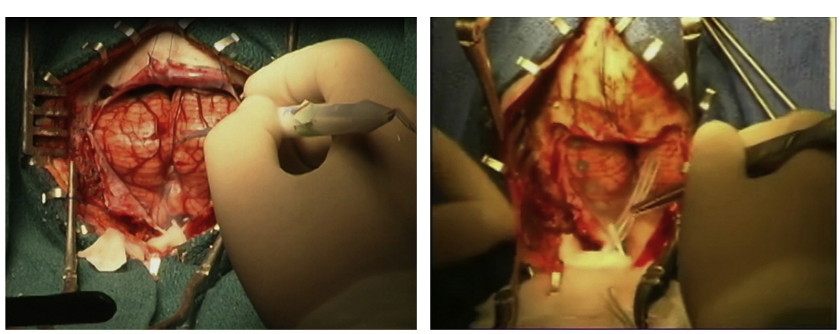

Fig. 1. Left panel: direct electrical stimulation of the cerebellar cortex with a bipolar electrode; right panel: recording somatosensory evoked potentials with cortex strip electrodes (4 contacts each).
Partie gauche : stimulation électrique directe du cortex cérébelleux avec une électrode bipolaire ; partie droite : enregistrement des potentiels évoqués somesthésiques à l'aide de grilles d'électrodes corticales (4 contacts chacune).

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