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PERSONAL VIEW/MISE AU POINT

The value of preoperative functional cortical mapping using navigated TMS

Intérêt de la cartographie corticale fonctionnelle préopératoire utilisant la TMS neuronaviguée

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Summary The surgical removal of brain tumours in so-called eloquent regions is frequently associated with a high risk of causing disabling postoperative deficits. Among the preoperative techniques proposed to help neurosurgical planning and procedure, navigated transcranial magnetic stimulation (nTMS) is increasingly performed. A high level of evidence is now available in the literature regarding the anatomical and functional accuracy of this mapping technique. This article presents the principles and facts demonstrating the value of using nTMS in clinical practice to preserve motor or language functions from deleterious lesions secondary to brain tumour resection or epilepsy surgery.

MOTS CLÉS
Aire de Broca ;
Cortex moteur ;
Langage ;
Neurochirurgie ;

Résumé L'exérèse chirurgicale des tumeurs cérébrales dans les régions dites éloquentes est souvent associée à un risque élevé de provoquer des déficits postopératoires handicapants. Parmi les techniques préopératoires proposées pour aider à la planification de la procédure neurochirurgicale, la stimulation magnétique transcrânienne neuronaviguée (nTMS) est de plus effectuée. À partir des données publiées dans la littérature, il existe à présent un haut niveau de preuve concernant l'exactitude anatomique et fonctionnelle de cette technique de cartographie. Cet article présente les principes et les faits qui démontrent la valeur de l'utilisation de

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la nTMS dans la pratique clinique pour préserver les fonctions motrices ou de langage de lésions délétères, secondaires à la résection d'une tumeur cérébrale ou à la chirurgie de l'épilepsie.

Introduction

Preservation of function during resection of pathological brain tissue is an essential objective of neurosurgery. Various neuroimaging and neurophysiological techniques have been proposed to perform preoperative brain mapping. One of the techniques most recently introduced in this context is transcranial magnetic stimulation (TMS), especially since this technique benefits from the integration of individual brain imaging data, using neuronavigation technology [70]. In this article, we present the principles and clinical applications of navigated TMS (nTMS) and describe how nTMS is effective to help neurosurgical practice in preserving motor or language functions from deleterious lesions secondary to brain tumour resection or epilepsy surgery.

Motor mapping

A compromise must always be obtained between the objective of completing the surgical removal of brain tumours in the rolandic region and the risk of causing or increasing postoperative motor deficit. To achieve maximal safe resections, neurosurgeons perform cortical and subcortical stimulation. Intraoperative stimulation mapping (ISM) provides reliable functional anatomical information on the cortical and subcortical location of motor control and represents the ''gold standard'' technique in this context [10,19,21,43,45]. However, to plan surgery and counsel patients based on an objective risk-stratification, it is beneficial to disclose the individual functional anatomy preoperatively. The relation between anatomy and function regarding the cortical motor areas frequently remains uncertain after standard anatomical magnetic resonance imaging (MRI), since brain tumours can cause anatomical distortion or induce plastic reorganization. Functional MRI (fMRI) was initially considered to be a reliable approach to assess motor cortical function preoperatively [60]. However, the accuracy and clinical relevance of this technique have increasingly been found disappointing in recent years [36,47,87], leaving room for other techniques. In recent years, nTMS has taken a prominent place in the field of presurgical functional mapping techniques, as a non-invasive approach to mimic ISM by probing the cortex with transcranially produced intracortical electrical stimulation.

The TMS technique was introduced in the mid 1980s as a non-invasive procedure to stimulate the motor cortex [7]. The recording of motor evoked potentials (MEPs), allowing the measurement of corticospinal tract motor conduction time is now accepted as a valuable investigation test in routine practice of clinical neurophysiology [14,80]. A few years after its introduction, the use of TMS to perform functional mapping of the motor cortex was proposed [16,61], including in preoperative testing [6,53,54]. However, the TMS methods performed at that time were not easy to apply and had limited anatomical precision. In the following years, various technological improvements were made, such as the development of navigation systems using individual data from brain imaging (MRI) to guide and readjust stimulation localisation information with greater anatomical precision [55,58,81]. At present, image-guided nTMS is validated in the indication of presurgical functional mapping of the motor cortex, e.g., approved by the Food and Drug Administration (FDA) in the USA (Ref. K091457, November 23, 2009).

To perform nTMS, as illustrated in Fig. 1, the patient sits comfortably in an examination chair and surface electrodes are placed on one or several muscle groups for recording MEPs, which is an electromyographic signal. The patient's head is co-registered with the TMS coil in the navigation system, in which high-resolution T1-weighted slices of the structural brain MRI of the patient have previously been integrated. The frameless stereotaxic system then allows determination of the location and orientation of the coil in real time over a 3D-reconstruction of the head and brain anatomy, with an infrared camera detecting reflectors (''trackers'') mounted on the patient's head and the TMS coil. The nTMS technique of cortical mapping is performed by stimulating multiple points on the scalp of the patient corresponding to the possible cortical motor regions and by concomitantly recording MEPs for each stimulation point. The stimulation intensity is usually maintained just above the rest motor threshold (RMT) to limit the neuronal excitation zone and to obtain the greatest functional anatomical accuracy. However, there is no consensus on which stimulation intensity level should be used [41] and for practical reasons, the different muscle representations are generally mapped with the same stimulation intensity. A figure-of-eight TMS coil is used, which generates a cone-shaped magnetic field, enabling ''focal'' stimulation. To achieve greatest mapping accuracy when investigating the precentral gyrus, the induced electric field has to be orientated perpendicular to the central sulcus and the mapping raster should be rather dense (approx. 2—5 mm spacing between stimulation spots). However, the orientation and the density of stimulation can be adapted in areas of particular interest, e.g. adjacent to a tumour, where the anatomy can be significantly distorted by the tumour mass and peritumoural oedema. The stimulated area must cover the precentral gyrus and the adjacent anterior and posterior gyri, since functionally relevant motor function can be located outside of the precentral gyrus [4,11,88].