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ORIGINAL ARTICLE / ARTICLE ORIGINAL

General principles for clinical use of repetitive transcranial magnetic stimulation (rTMS)

Utilisation clinique de la stimulation magnétique transcrânienne répétitive (SMTr) : principes généraux

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KEYWORDS
Repetitive transcranial magnetic stimulation;
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Motor cortex;
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Depression

Abstract Repetitive transcranial magnetic stimulation (rTMS), a non-invasive technique allowing stimulating neurons in the cerebral cortex, is able to modify durably local as well as distant neuronal activity. Results obtained by stimulation of the primary motor cortex and measurements of induced muscle responses suggest that effects on cortical excitability depend on stimulation frequency and intensity, as well as of pulse-train duration. Such data, as well as results of animal studies have brought a physiological basis for the use of rTMS for treatment of various neurological and psychiatric disorders, and particularly depression. Nevertheless, as long as large randomized studies have not been conducted, rTMS should not replace other existing and validated therapies.

MOTS CLÉS
Stimulation magnétique transcrânienne répétitive ;
SMTr ;
Traitement ;
Cortex moteur ;
Cortex préfrontal ;
Dépression

Résumé La stimulation magnétique transcrânienne (TMS), un outil non invasif permettant de stimuler électriquement les neurones du cortex cérébral, est capable de modifier durablement l'activité neuronale localement et à distance lorsqu'elle est administrée sous forme de trains d'impulsions. Les résultats de la stimulation du cortex moteur suggèrent que le type d'effet sur l'excitabilité corticale dépend de la fréquence de stimulation. Ces données, ainsi que les résultats d'études animales ont apporté une base théorique pour utiliser la stimulation magnétique transcrânienne répétitive (SMTr) pour traiter diverses affections cérébrales et en particulier la dépression. Toutefois, tant que de larges études randomisées n'ont pas été conduites, on ne peut proposer la SMTr comme alternative de routine aux traitements existants et validés.

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Introduction

Transcranial magnetic stimulation (TMS) allows relatively painless and non-invasive activation of relatively superficial excitable cerebral structures [25]. Briefly, a powerful bank of capacitors is instantaneously discharged through circular copper wires embedded in resin, named "coil". This induces a strong but transient magnetic field (1–4 T, depending on the shape and size of the coil), which is able to cross soft tissue and bony parts such as the skull with little attenuation. This transient magnetic field induces itself an electric current in surrounding structures, circulating in the opposite direction to the current flowing in the coil (Fig. 1). This transient electrical current is able to activate excitable structures located in the vicinity (neurons, axons, muscles). The induced electric current decays exponentially with the distance. It is generally estimated that for brain stimulation with large conventional circular coils placed tangentially on the scalp, only cortical areas can be reached, as the maximal depth of penetration of the magnetic field is about 30 mm, and the cerebral cortex surface lies some 20 mm under the skin [25]. Fields of smaller or eight-shaped coils penetrate even less. Only double, cone-shaped coils with large loops might induce electric fields which could reach subcortical structures. In the case of motor cortex stimulation, it has been demonstrated that when circular magnetic coils are placed tangentially to the scalp, for example centered at the vertex for hand area stimulation, corticospinal tract is mostly activated transsynaptically, through interneurons [9,27]. When the coil is displaced laterally, inducing a current more parallel to the direction of corticospinal axons, then direct activation of such axons can occur, even with relatively weak stimulus intensities. As several structures converging onto the pyramidal tract neuron (PTN) can be activated by TMS, it is easy to understand that a single pulse induces successive descending volleys in PTN axons, the sequence of which depends on the coil shape and orientation, and stimulus intensities. Such volleys are named D and I waves, the former, with shortest latency, caused by direct activation of PTN axons while the latter are the result of interneuron activation (Fig. 2).

Thus, larger coils are more efficient than small or eight-shaped ones, but what they gain in efficacy is lost in spatial resolution. Indeed, maximal electric currents are induced near the outer edge of circular coils, being thus able to activate excitable structures all around the coil. With eight-shaped coils, at least for moderate intensities, the maximal electric current is induced at the intersection of both loops, thus allowing better focalizing the stimulation

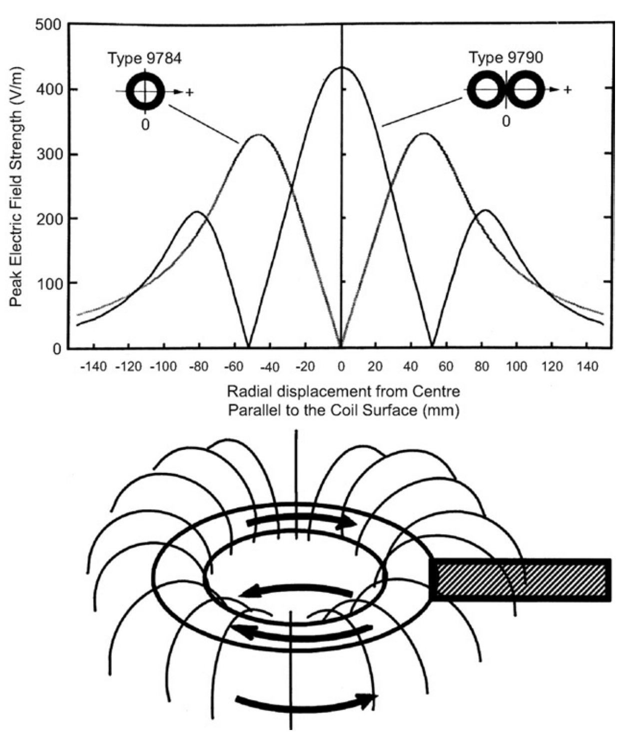

Figure 1 a: Electric fields induced by circular and eight-shaped coils. b: The direction of the induced current is opposite to that in the coil.

Figure 2 Intra- and extra-cellular pyramidal recordings following single anodal stimulus of motor cortex at three different intensities. Multiple descending volleys are elicited by single pulses, the number of which increases with stimulus intensity. TMS evokes similar responses, except that the earliest wave (D-wave) is less often elicited with traditional coil position (see text) [27].