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Co-registration of magnetic resonance spectroscopy and transcranial magnetic stimulation

Antoine Hone-Blanchet[a,*], Rachel E. Salas[b], Pablo Celnik[c], Aadi Kalloo[b], Michael Schar[e], Nicolaas A.J. Puts[d,e], Ashley D. Harris[d,e], Peter B. Barker[d,e], Shirley Fecteau[a,f], Christopher J. Earley[b], Richard P. Allen[b], Richard A. Edden[d,e]

[a] Laboratory of Canada Research Chair in Cognitive Neuroscience, Centre Interdisciplinaire de Recherche en Réadaptation et Intégration Sociale, Centre de Recherche de l'Institut Universitaire en Santé Mentale de Québec, Faculty of Medicine, Laval University, QC, Canada
[b] Department of Neurology, The Johns Hopkins University School of Medicine, Baltimore, MD, USA
[c] Department of Physical Medicine and Rehabilitation, The Johns Hopkins University School of Medicine, Baltimore, MD, USA
[d] FM Kirby Center for Functional Brain Imaging, Kennedy Krieger Institute, Baltimore, MD, USA
[e] Russell H. Morgan Department of Radiology and Radiological Science, The Johns Hopkins University School of Medicine, Baltimore, MD, USA
[f] Berenson-Allen Center for Noninvasive Brain Stimulation, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MS, USA

HIGHLIGHTS

- We demonstrate a workflow of co-registration and co-visualization of TMS and MRS.
- TMS delivery over the MRS voxel of interest elicited a physiological response.
- MRS voxel location can reliably localize the motor cortex subsequently validated by TMS.
- Co-registration of TMS and MRS is feasible and will be useful in future neurophysiological studies.

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ABSTRACT

Transcranial magnetic stimulation (TMS) is a widely used tool for noninvasive modulation of brain activity, that is thought to interact primarily with excitatory and inhibitory neurotransmitter systems. Neurotransmitters such as glutamate and GABA can be measured by magnetic resonance spectroscopy (MRS). An important prerequisite for studying the relationship between MRS neurotransmitter levels and responses to TMS is that both modalities should examine the same regions of brain tissue. However, co-registration of TMS and MRS has been little studied to date. This study reports on a procedure for the co-registration and co-visualization of MRS and TMS, successfully localizing the hand motor cortex, as subsequently determined by its functional identification using TMS. Sixteen healthy subjects took part in the study; in 14 of 16 subjects, the TMS determined location of motor activity intersected the $(2.5\,\mathrm{cm})^3$ voxel selected for MRS, centered on the so called 'hand knob' of the precentral gyrus. It is concluded that MRS voxels placed according to established anatomical landmarks in most cases agree well with functional determination of the motor cortex by TMS. Reasons for discrepancies are discussed.

1. Introduction

Transcranial magnetic stimulation (TMS) is a noninvasive brain stimulation technique that uses the principles of electromagnetic induction to induce an electric current within the surface of the human cortex. This current may be of sufficient intensity to depolarize neurons in a certain area (Wagner et al., 2009). Single-pulse and paired-pulse TMS paradigms can be used in the evaluation of cortical excitability with measurements of short interval cortical inhibition (SICI), intracortical facilitation (ICF), and long interval cortical inhibition (LICI) (Kujirai et al., 1993). These measurements of the motor cortex excitability are widely applied in cognitive and clinical neuroscience, for example, to assess cortical function or neuronal damage in neurological conditions

* Corresponding author at: Centre Interdisciplinaire de Recherche en Réadaptation et Intégration Sociale, 525, boulevard Hamel, bureau H-1312, Québec City, QC, G1M 2S8 Canada. Tel.: +1440114185299141x2460.
E-mail address: antoine.hone-blanchet.1@ulaval.ca (A. Hone-Blanchet).

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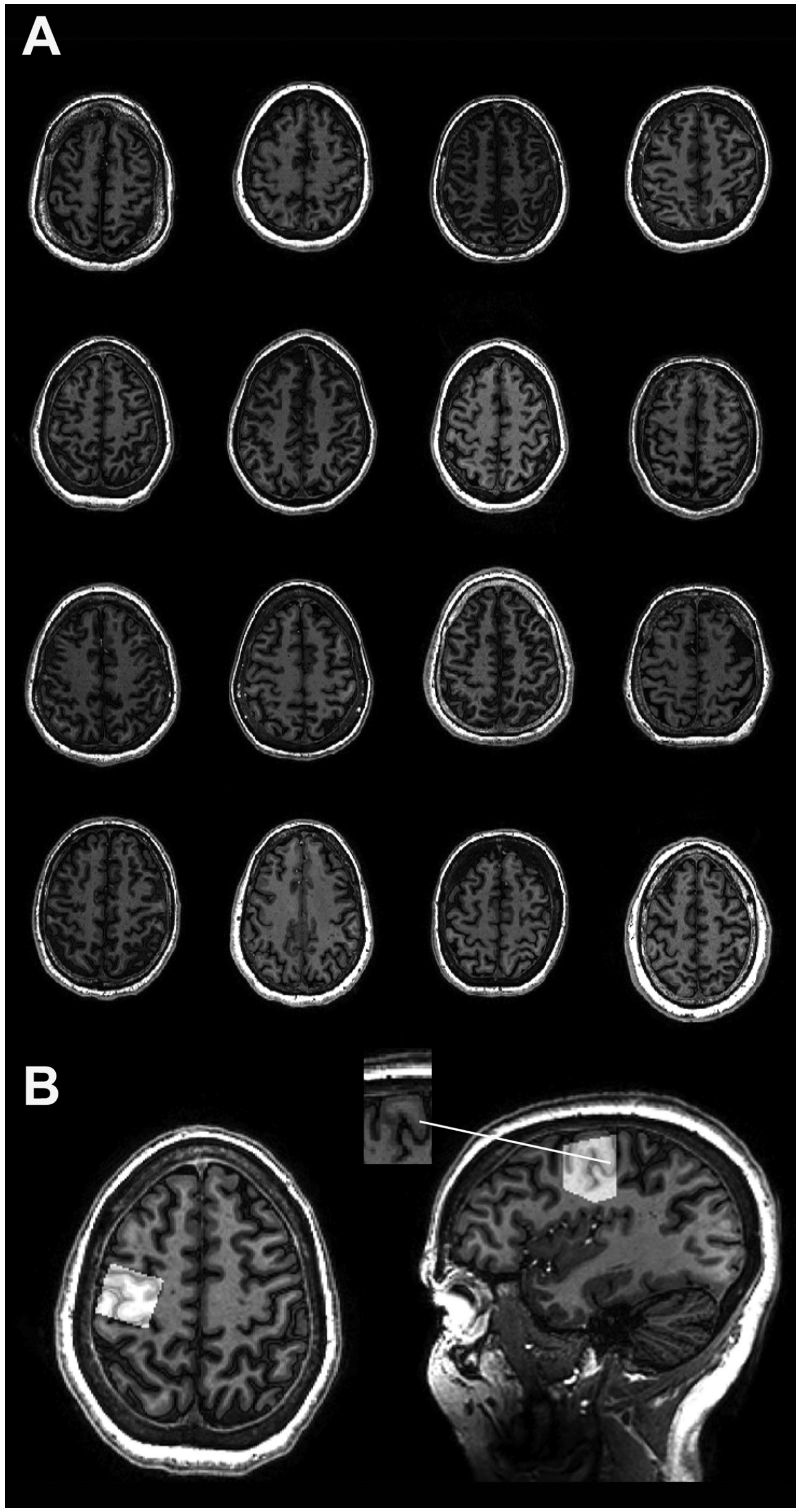

Fig. 1. Hand knob anatomy and MRS voxel location. (A) T1-weighted axial images for the slice containing the hand knob in each of the sixteen subjects. Eight subjects showed the classic bilateral single-lobe hand knob; seven showed a more complicated two-lobed (or more) variant; one subject showed this form bilaterally. (B) MRS voxel location (light gray) superimposed on the MRI. In the axial slice the voxel was positioned so as to include all of the hand knob and minimal postcentral tissue. The hand knob appears in the sagittal slice as a rear-facing hook.

(Bares et al., 2003; Pascual-Leone, 2006) and to measure the effect of pharmacological compounds (Feil and Zangen, 2010). If administered repetitively, TMS may elicit significant cortical excitability changes that outlast the period of stimulation. These long-lasting changes are associated with neuronal plasticity and may promote cognitive and behavioral changes (Wassermann and Lisanby, 2001). TMS applied to the primary motor cortex with electromyographic (EMG) recording of motor-evoked potentials