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Preoperative functional mapping for rolandic brain tumor surgery

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HIGHLIGHTS

- nTMS is a technology used for preoperative functional mapping of motor cortex.
- Our experience of use of nTMS in functional mapping of rolandic brain tumors.
- nTMS reduces surgical-related post-operative motor deficits.

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ABSTRACT

The resection of tumors within or close to eloquent motor areas is usually guided by the compromise between the maximal allowed resection and preservation of neurological functions. Navigated transcranial magnetic stimulation (nTMS) is an emerging technology that can be used for preoperative mapping of the motor cortex. We performed pre-surgical mapping by using nTMS in 17 patients with lesions in or close to the precentral gyrus. The study was conducted on consecutive patients scheduled for surgical treatment. nTMS allowed to exactly localize the motor cortex in 88.2% of cases. In 70.6% it provided the surgeon with new unexpected information about functional anatomy of the motor area, influencing the pre-operative planning. Moreover, in 29.4% these functional information had a clear impact on surgery, making necessary a change of surgical strategy to avoid damage to the motor cortex. Our results prove that nTMS has a large benefit in the treatment of rolandic brain tumors. It adds important information about spatial relationship between functional motor cortex and the tumor and reduces surgical-related post-operative motor deficits.

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1. Introduction

The resection of tumors within or close to eloquent motor areas and particularly the pre-central gyrus is usually guided by the compromise between the maximal allowed resection and preservation of neurological functions [1,2]. Especially in gliomas, surgical tumor reduction significantly affects survival and thus must be as radical as possible [3,4]. On the other hand neurosurgeons must preserve hand motor function and language areas to guarantee a good quality of life for patients. To achieve this important goal it is necessary to use a multimodal approach in order to assess the integrity of corticospinal tracts as well as motor function pre-surgically and during tumor resection [5,6]. Preoperative delineation of motor cortex with brain imaging approaches can potentially provide spatial information on cortical areas that are involved in voluntary movements thus depicting all regions that participate in the movement or are activated by the sensory feedback from the movement. Nevertheless preoperative neuroimaging evaluation of the primary motor area, in cases of rolandic brain tumors, has been unsatisfactory because the effects of peri-tumoral edema, anatomical distortions, and changing in vasculature can disrupt the otherwise excellent spatial resolution of neuroimaging technologies [7,8]. Therefore direct cortical stimulation (DCS) is still the gold standard used by neurosurgeons to define eloquent areas [9]. Electrical stimulation of the brain through the intact skull is made difficult as the high electrical resistances require large electrical currents that lead to painful muscle contractions making this approach not suitable for pre-operative surgical planning. On the other hand transcranial magnetic stimulation (TMS) is an alternative method of

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stimulating the brain through the intact scalp without causing pain at the surface [10]. TMS has the great advantage that does not require active participation of the subject, which is a current limitation of imaging studies. In addition TMS can also be used for establishing accurate motor maps and monitoring cortico-spinal pathways or is combined with neuroimaging techniques such as fMRI for the manipulation of complex brain network interactions. However an important limitation of standard TMS is that such a method, based on standard coil location with respect to external landmarks of the skull, would not be acceptable for an accurate preoperative cortical mapping. Anatomical measurements of in vivo brain macroscopic anatomy have shown that the anterior-posterior shift in the location of the central sulcus with respect to the Talairach coordinate system is ±1.5–2 cm [11] and the variation is likely to be significantly larger with respect to external skull landmarks. This variability is greatly increased by brain pathology when anatomical structures are smeared by tumors, edema and vascular alterations. The spatial accuracy has been recently achieved by the introduction of a new technique, the so-called navigated transcranial magnetic stimulation (nTMS) [12]. The core concept in TMS-navigation is an accurate GPS-like navigator, where structural brain maps acquired using MRIs are used in place of street maps [12]. In particular navigation is based on the patient's MRI scan and proprietary electric field modeling, showing the location and orientation of TMS-stimuli inside the brain. In this way it is possible to detect and map, with great precision, some of the eloquent areas such as motor and language areas.

In a recent study Picht et al. measured the accuracy of preoperative nTMS system against the gold standard of intra-operative DCS in determining the motor area hotspot [12]. The mean distance between the TMS and DCS hotspots was less than 5 mm for hand muscles suggesting that nTMS is a suitable technique in a clinical pre-surgical setting. This is why we decided to introduce, in line with other groups, nTMS as a routinely preoperative functional mapping of Rolandic and peri-rolandic brain tumors.

In the present paper we report the experience gained during the first year of systematic use of nTMS.

2. Materials and methods

The present study was conducted in accordance with the ethical standards of the University of Messina, the local ethics committee, and the Declaration of Helsinki. Informed consent was obtained from every patient.

2.1. Patient population

nTMS based pre-surgical mapping was carried out on 17 consecutive patients with lesions within or close to the precentral gyrus, as well as in the subcortical white matter motor pathways. Nosographic data and neurological status at admission for all cases are reported in Table 1. Exclusion criteria for brain stimulation were the existence of a pacemaker or deep brain stimulation electrodes. Patients were thoroughly examined for handedness, paresis, spasticity, medical history, and current use of medication. Arm motor performance was graded using the Action Research Arm Test (ARAT) [13] preoperatively, on the day of discharge, and on postoperative follow-up (3 months).

Table 1
Summary of patients' epidemiological data and ARAT scores. Nosographic data and neurological status for all 17 consecutive patients with lesions within or close to the precentral gyrus, as well as in the subcortical white matter motor pathways.

Number and initials	Age, sex	Handedness	Tumor location	Histology	AEDs	Pre-Op ARAT score	Post-op ARAT score at discharge	Post-op ARAT score during follow-up
# 1, BE	70, F	R	MC I, right	Oligodendroglioma	LEV	44/57	44/57	48/57
# 2, FF	60, M	R	MC I right	MTS Lung Cancer	PB	18/57	23/57	26/57
# 3, PS	40, M	L	MC I, right	Limphoma	OXZ	50/57	50/57	50/57
# 4, TSA	48, F	R	S I, left	MTS Lung Adenocarcinoma	LEV	46/57	48/57	48/57
#5, CE	38, M	R	Fronto-opercular-insular, left	Diffuse Astrocytoma	LEV	51/57	50/57	50/57
#6, GMS	78, F	R	S I, left	Anaplastic Astrocytoma	LEV	38/57	41/57	42/57
#7, PCW	26, M	R	MC I, left	Cavernous Angioma	PB	50/57	49/57	50/57
#8, BS	43, F	R	Fronto-opercular-insular, left	Diffuse Astrocytoma	OXZ	48/57	52/57	52/57
#9, RAA	51, M	R	S I, left	Transitional Meningioma	LEV	32/57	34/57	44/57
#10, RR	37, F	R	MC I, right	Cavernous angioma	LEV	43/57	52/57	49/57
#11, LMG	54, F	L	S I, right	Glioblastoma Multiforme	LEV	48/57	46/57	48/57
#12, RS	34, F	R	MC I + S I, right	Glioblastioma Multiforme	–	16/57	23/57	22/57
#13, GF	51, M	R	MC I, right	Glioblastoma Multiforme	PB	19/57	21/57	20/57
#14, SV	49, M	L	Fronto-temporo-insular, right	Glioblastoma Multiforme	LEV	37/57	42/57	44/57
#15, LCT	39, F	R	Fronto-temporo-insular, right	Oligoastrocytoma	LEV	45/57	47/57	50/57
#16, PM	68, F	R	MC I + S I, left	Arachnoid cyst	–	41/57	30/57	32/57
#17, GR	82, F	R	S I, left	MTS colon cancer	–	52/57	51/57	52/57

Legend: PB = Phenobarbital, LEV = Levetiracetam, OXZ = Oxcarbazepine, MCI = Primary Motor Cortex; S I = Primary Somestesic Area, MTS = Metastasis.

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