

# Chapter XVII

## Brain Mapping in Functional Neurosurgery

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### ABSTRACT

*Functional brain mapping is a procedure that can be used to identify cortical areas that mediate sensorimotor and higher cognitive brain functions, such as language, attention, memory, and cognition. Clinically, it is currently used for preoperative surgical planning in patients suffering from intractable epilepsy and brain tumors, and may soon have significant applications in brain injury, stroke, dementia, and developmental disorders. Functional brain mapping is also a very powerful research tool in the area of cognitive neuroscience and, lately, in psychiatry. Recent technological advances in neuroimaging techniques, the development of large sensor arrays, the use of sophisticated computer systems and superior graphics, gradually make more apparent the relevance of this technique in providing answers to complex questions about the structural and functional connectivity of the brain, and the way it represents and processes information.*

### INTRODUCTION

Functional neurosurgery refers to those surgical interventions that are intended to improve the function of the central or peripheral nervous system. It is usually reserved for chronic neu-

rological diseases resistant to drug therapy, such as refractory epilepsy, Parkinson's disease, essential tremor, and intractable chronic pain. Ablative procedures entail the permanent disconnection of certain neural pathways, while augmentative ones make use of implantable

devices that modulate the function of dysfunctional neuronal assemblies through the chronic electrical stimulation of specific neuronal pathways.

In all cases, accurate localization of the intended surgical target and of the cortical areas that are responsible for vital brain functions, such as sensation, movement, and speech, is of paramount importance because resection of such critical brain areas can have devastating results. The procedure employed is called functional brain mapping and aims at visualizing the relationship between neural structures and their function.

## **BACKGROUND**

During the past several years, a number of noninvasive functional imaging modalities, including functional magnetic resonance imaging (fMRI; Binder, Frost, Hammeke, Cox, Rao, & Prieto, 1997), positron-emission tomography (PET; Peterson, Fox, Posner, Mintun, & Raichle, 1998), regional cerebral blood flow (rCBF; Friberg, 1993), and single-photon-emission computed tomography (SPECT; Gomez-Tortosa, Martin, Sychra, & Dujovny, 1994), have been used to map brain function with varying degrees of success. However, the most reliable approach to date still relies on direct electrical stimulation of the exposed cortex (Ojemann, Ojemann, Lettich, & Berger, 1989), a procedure that is highly invasive and unpleasant, and is performed mostly intraoperatively on an awake patient.

More recently, however, completely noninvasive procedures have been successfully used for brain mapping (Ebersole & Wade, 1990; Peterson et al., 1998; Zouridakis, Simos, Breier, & Papanicolaou, 1998). These procedures rely on the fact that the performance of certain brain functions involves only a small

population of cortical neurons whose activation gives rise to electromagnetic signals that can be recorded outside the head. The electrical aspects of brain activation can be recorded in an electroencephalogram (EEG) by placing a set of electrodes on the scalp, while the corresponding magnetic aspects can be captured in a magnetoencephalogram (MEG) by placing an array of coils in close proximity to the head. Brain-mapping procedures based on the combination of high-resolution MRI and EEG or MEG recordings are known as electrical source imaging and magnetic source imaging, respectively.

In general, MEG systems are expensive as they require special cryogenic equipment, a magnetically shielded room, and daily monitoring and maintenance. They are also only available in a handful of places around the world, so the clinical usefulness of MEG is limited. On the other hand, EEG equipment is portable, does not require any special maintenance, is readily available in practically all clinical settings, and even the most sophisticated systems that incorporate dense-array sensors are at least one order of magnitude less expensive than MEG. Moreover, recent advances in hardware and the development of new mathematical tools for modeling the intracranial sources and the head make dense-array EEG (*d*EEG) a very attractive methodology because it can provide a temporal resolution of one millisecond or less and a very high spatial sampling. Therefore, brain mapping based on *d*EEG and MRI can have a significant impact on patient care. A state-of-the-art *d*EEG system (ActiveTwo, BioSemi, The Netherlands) that is available in our lab features 256 recording channels for whole head coverage at a sampling rate of 5 kHz per channel and uses active electrodes with built-in preamplifiers for noise cancellation.

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