



Brain Mapping and Neuroscience

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This issue of the journal is allocated to brain mapping. The current neurosurgical innovations aim to improve our anatomical, physiological, and functional understanding of the surgical region of interest to prevent potential neurological morbidity during surgery. The primary tenet of neurosurgical oncology is that survival can improve with greater tumor resection. To map the horizon, different techniques have been developed to clarify the human brain physiology and to optimize safe lesion resection during surgery.

Functional magnetic resonance imaging (fMRI) is based on the increase in blood flow to local vasculature that accompanies neural activity in the brain. These results in a corresponding local reduction in deoxyhemoglobin because the increase in blood flow occurs in the absence of a comparable increase in oxygen extraction. Thus, deoxyhemoglobin is used as an endogenous contrast-enhancing agent and serves as the source of signal during fMRI. The results of fMRI can be consistent with electrophysiology, positron emission tomography, cortical stimulation, and magneto-encephalography and are used to provide preoperative functional and structural information for neurosurgery. Cortical stimulation based on local circuit disruption, best identifies areas that are essential to eloquent motor and language processing and still remains the gold standard. fMRI is an activation-based method that identifies all regions of the brain demonstrating activity related to a particular task regardless of whether those areas are essential or supplementary. Consequently, areas that appear negative for language when cortical stimulation is used may still demonstrate fMRI activation, producing false-positive results. Decreased specificity may also be expected because fMRI is a perfusion-based method and does not directly detect neuronal activity (1).

Magnetic resonance perfusion and cerebral blood volume magnetic resonance imaging techniques have been developed for the assessment of cerebral blood volume (CBV). Because the vasculature plays a pivotal role in tumor growth and infiltration, particularly for gliomas, and

affects drug delivery and effectiveness of radiotherapy, in vivo assessment of vascular properties of brain tumors is critical. Thus, visualizing the degree of vascular proliferation is important in determining the biological aggressiveness and histopathological grading of tumors such as gliomas. Tissue oxygen content, determined by the balance between oxygen delivery and consumption, directly influences the efficacy of radiotherapy. Therefore, it is of potential value to characterize the vascularity of gliomas and changes in vascularity associated with therapy. In examining the permeability and blood volume profiles of many tumors, it is now possible to localize tumor extension beyond the enhancing margin of the lesion.

Diffusion tensor imaging (DTI) as an emerging neuroimaging modality also allows the examination of specific neural components such as the integrity of white matter tracts. This technique is based on the paradigm of fractional anisotropy, which is related to diffusion-weighted imaging. It allows, among other things, the identification of subcortical white matter tracts and a preoperative determination of their course relative to the surgical target. Typically, some form of tensor directional mapping, either with or without fiber tracking, is used to depict the dislocation of a fiber tract by tumor. Some investigators have integrated DTI-based tractography with cortical mapping using fMRI or intraoperative electrocortical stimulation using the results of cortical mapping to provide seed locations to the tractography algorithm. DTI-based fiber tract maps can provide confirmation that a tract in question remains intact and informs the surgeon as to the tract's location with respect to the tumor, possibly facilitating the tract's preservation at surgery. Using subcortical stimulation mapping to measure the accuracy of DTI fiber tracts in deep white matter, studies have confirmed that DTI fiber tracks can be used to define a safety margin around the motor tract for use in surgical planning (2).

Magnetoencephalography (MEG) has also been increasingly used for preoperative functional mapping. Compared with fMRI and positron emission tomography,

MEG has the advantage of higher temporal resolution by directly measuring neuronal activation rather than indirect hemodynamic change. Previous studies have also suggested that MEG is more accurate than fMRI in identifying functional cortices that have been distorted by a nearby tumor. Overall, MEG is a robust and reliable functional imaging modality that is now used to identify the cortical location of motor and sensory pathways. Integrating MEG data with DTI information into a neuronavigational workstation directs the neurosurgeon toward potential functional sites that can be intraoperatively confirmed using stimulation mapping.

Although many of the aforementioned modalities generally provide static images of neural function and physiology, future neuroimaging will focus on functional connectivity. In this respect, MEG is now evolving to measure connectivity based on the principle of imaginary coherence, which is a mathematical modeling paradigm that allows connections between cortical regions to be elucidated based on the neuro-oscillations within that cortex.

Magnetic resonance spectroscopy (MRS) is now considered by many to be the gold standard among the physiological imaging technologies. It is a powerful non-invasive imaging technique that offers unique metabolic information on brain tumor biology. Beyond its diagnostic capabilities, MRS is becoming increasingly useful in the operating room, where imported MRS images can be integrated into the neuronavigational workstation to define the lesion not just anatomically, but in terms of the disease around it. Although incorporating this technology into the surgical strategy can influence a planned extent of resection, it can also guide stereotactic biopsies for higher diagnostic yields.

Although a primary tenet of neurosurgical oncology is that survival can improve with greater tumor resection or even supra-radical tumor excision, this principle must be tempered by the potential for functional loss after radical removal. The current neurosurgical innovations aim to improve our anatomical, physiological, and functional understanding of the surgical region of interest to prevent potential neurological morbidity during resection (3).

In this issue, we review the current and future imaging modalities as well as the state-of-the-art intraoperative techniques that can facilitate the extent of resection while minimizing the associated morbidity profile. Physiological imaging has emerged as one of the most important adjuncts available in neurosurgery. By transitioning from a purely anatomy-based discipline to one that incorporates functional, hemodynamic, metabolic, cellular, and cytoarchitectural alterations, the current state of neuroimaging has evolved into a comprehensive diagnostic tool that allows the characterization of morphological and biological

alterations to diagnose and grade brain tumors and to monitor and assess treatment response and patient prognosis.

Footnotes

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