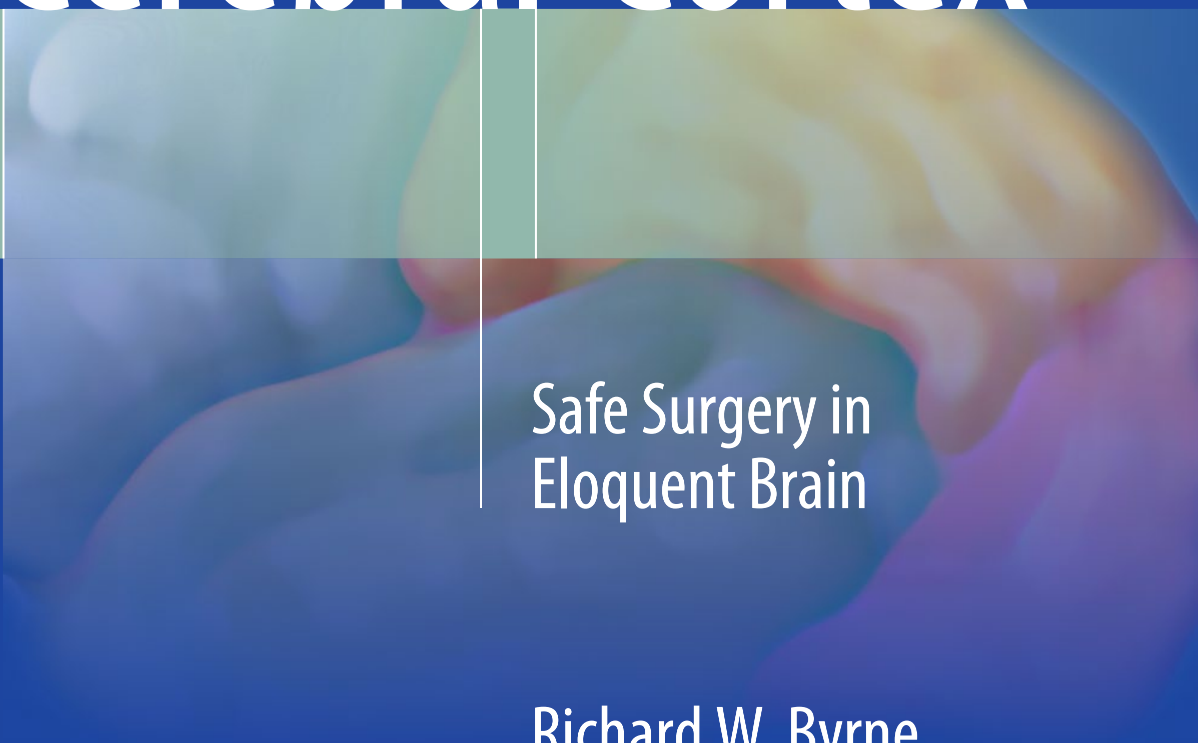
Functional Mapping of the Cerebral Cortex



Safe Surgery in Eloquent Brain

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Richard W. Byrne, M.D.

Foreword

It is an honor and pleasure to be asked to write a foreword to this splendid volume on *Functional Mapping of the Cerebral Cortex*.

After having spent 35 years performing resections of epileptic foci, and trying in each case to determine with precision where we are over and within the brain, it is refreshing, instructive, and useful to see such an updated gathering of practical information on this important topic.

Techniques of cerebral mapping were developed mostly for resection of epileptic foci and brain tumors. While the early history of the brain motor responses upon stimulation reflects the collective and cumulative efforts of many neurosurgeons, the confirmation of the sensory strip resulted from the work of a single man, Harvey Cushing, in 1909.

If one had to pick a single work on cerebral mapping characterized by its thoroughness and usefulness, it should be that of Penfield and Boldrey of 1939. It illustrates the early and systematic work of Penfield and collaborators at the Montreal Neurological Institute. Over the years, the so-called Montreal procedure was used for all types of resections but mostly for temporal lobe epilepsy. Stimulation studies were systematically carried out under local anesthesia to identify the sensory strip, mainly the tongue area, to determine the position of the central sulcus and the extent of the resection along the Sylvian fissure. Identification of speech centers was more complicated, giving rise often to negative responses and anxiety. The parameters used became of paramount importance.

There came a point in time where enough physiological data gathered could be transposed to morphology. To what extent the surgeon can nowadays rely on morphological landmarks and preoperative data only is of crucial importance. With the advent of three-dimensional reconstruction and the integration of physiological findings, the process of cerebral mapping starts before the actual surgical procedure. Using navigation, the preliminary identification of the motor, sensory, and speech centers can be used for centering the craniotomy and zooming on the areas to be visually recognized and stimulated. This approach has led to smaller craniotomies often to the detriment of electrocorticography. However, in spite of their usefulness and precision, these techniques have not replaced the need for peri-operative confirmation. They rather serve to optimize the whole process of localization.

A significant advantage of peri-operative stimulation is the need to have the patient awake and cooperating, which allows not only for the acquisition of physiological data but also for the detection of an eventual early and reversible deficit. Close collaboration with anesthesia is essential and the expertise in conducting awake procedures cannot be overemphasized.

A safe removal does not relate strictly to the extent, compactness, and cruciality of the tissue resected but also to the consequence of vessels occlusion deliberate or not, venous or arterial, in the actual process of resection.

The various techniques described in this book will help the young neurosurgeon interested in the resection of epileptic foci and brain tumors to develop his own way of finding out precisely where he is over and within the brain, recognize eventual pitfalls, and avoid complications.

Montreal, QC, Canada André Olivier, M.D., Ph.D.
June 2015

Preface

The purpose of this book is to give practical guidance to clinicians and scientists (neurosurgeons, neurologists, neuroradiologists, neurophysiologists, neuropsychologists, and those in training in these disciplines) in their encounters with the difficult and commonly encountered problem of treating patients with lesions in eloquent cortex. These cases represent some of our greatest challenges in clinical medicine, but they also represent our opportunity to potentially make the greatest positive impact for our patients. Through careful consideration of the indications for an intervention, proper choice of brain mapping technology, and proper execution of brain mapping techniques, we are now able to offer some of our most challenging patients a safer and more effective intervention. This is made possible through a combination of advantages that brain mapping offers. First, brain mapping techniques may identify the cases in which we should not offer an invasive procedure, saving patients from operative morbidity. Second, brain mapping can show us when we can offer a more radical procedure than indicated by our imaging technology and by presumed functional localization. Finally, brain mapping can show us when we need to stop in order to avoid permanent morbidity by giving preoperative localization clues and intraoperative immediate feedback on the impact of our intervention.

The art and science of brain mapping once was the purview primarily of epilepsy surgeons. In fact, it is in this aspect of my practice that I learned and became comfortable with the various techniques of brain mapping. As both brain mapping and operative technology have advanced over the past 25 years since I first participated in a brain mapping operation, it has become more clear that this discipline could be adopted more widely by practitioners who rarely encounter operative epilepsy conditions, but rather commonly encounter intra-axial lesions such as glioma, metastasis, and congenital and vascular lesions. In fact, intra-axial lesions have become a common indication for brain mapping. Widespread acceptance and adoption of brain mapping techniques has occurred over the past 10 years. However, many practitioners have not had extensive training in brain mapping techniques and lack an understanding of the advantages and limitations of the various brain mapping techniques available. As such, many clinicians seek training in brain mapping in order to bring the advantages of brain mapping to their patients. While teaching and training residents and practicing clinicians in brain mapping, it became apparent to me that there was a need for a practical guide to brain mapping, bringing together the extra- and intraoperative techniques and technologies. This textbook is our effort to provide this guide. In doing so, I have partnered with many of the most respected leaders in this field who have generously given their clear and careful practical guidance in their particular expertise. I am grateful for their generosity in sharing their time and experience.

The structure of the textbook emphasizes the progression of the various ways that eloquent cortex can be identified. First and foremost is anatomy. In this chapter the classic anatomic-functional correlations essential for any neurosurgeon, neurologist, or neuroscientist to achieve an understanding of brain mapping are described. As neuroanatomy is highly conserved in evolution, knowing the sometimes subtle but reliable nuances of neuroanatomy is all that is necessary to proceed with safe treatment in many cases of nonlesional or lesional neurosurgery remote from eloquent cortex. This may also be the case in a limited number of well-circumscribed lesional cases located at the surface in and around eloquent cortex. There are, however, limits to this anatomical localization. Certainty of anatomic localization is often limited in identifying areas necessary for speech function. Variable localization and in some cases even lateralization of speech function introduces uncertainty in an area that requires near certainty. Furthermore, the nature of lesional neurosurgery necessarily causes distortions in normal anatomy, and in some cases neural plasticity may cause relocation of function. Because of this, preoperative and intraoperative adjuncts in functional localization are often necessary.

The various forms of image-based functional localization have evolved over time to become more reliable and more available to practitioners. This has paralleled rapid advances in imaging technology. The history of the development of functional localization highlights the necessary reliance of brain mapping on the progress of applied technology. Early mapping efforts focused on direct recording of evoked potentials and direct cortical stimulation. Indirect noninvasive forms of mapping based on functional metabolic, electrical, and magnetic signals have continued to expand our understanding of brain function. Their ability to display all brain regions involved in a cerebral function has been their strength, but also their weakness. From a research perspective, this high level of sensitivity is ideal. From an operative decision-making standpoint, this is a weakness.

The ideal mapping technique from the standpoint of a clinician balances sensitivity and specificity for localization of truly essential cortex, as opposed to all merely involved cortical areas. Because of this, a major focus of this textbook is intraoperative and extraoperative cortical stimulation mapping techniques and practical decision-making. The described technique of "negative mapping" is described extensively in one chapter and emphasizes the advantages of this technique in brain tumor cases. Cortical stimulation mapping, with or without the awake technique, remains our gold standard in cases of lesional and nonlesional pathology involving eloquent cortex. This mapping may be done intra- or extraoperatively and can be combined with extraoperative imaging and metabolic mapping technologies. Because cortical stimulation mapping identifies essential cortex, and imaging technologies display the wider areas of diffusely involved functional cortex, the techniques are complementary. We have gathered several chapters with slightly different points of view on indications, protocol, and technique to highlight the variety of ways cortical mapping can be used in both lesional and nonlesional epilepsy and brain tumor surgery. These chapters along with chapters highlighting indications, extraoperative mapping, intraoperative evoked potential monitoring, and anesthetic techniques offer the clinician and scientist a guide to the various options available for modern brain mapping. We have highlighted key points and have provided illustrative cases demonstrating practical applications of brain mapping.

We have also included chapters hinting at what may become a growing part of the future of brain mapping. Intra- and extraoperative techniques of gamma frequency EEG mapping and extraoperative transcranial magnetic stimulation are quickly advancing through the research phase and may soon become a routine part of clinically applied brain mapping. Although today's practitioners are becoming well versed in the accepted techniques and technology available now, we will all welcome the day when these and other technologies will mature and help us make caring for patients with pathology in eloquent cortex safer and more effective.

Finally, I would like to end with a word about clinical judgment. No matter what technology is available to clinicians treating patients with pathology in eloquent cortex and eloquent white matter connections in the brain, it must be emphasized that it takes experienced clinicians working in multidisciplinary teams with a well-informed patient to weigh decisions to operate, or not operate in these cases. The same applies to the choice of which technique or technology to employ. No technique that we describe here completely guards against operative morbidity. In fact, operating in eloquent cortex commonly leads to temporary morbidity that must often be accepted and anticipated by the practitioner and patient alike. A judicious balancing of the risks of an intervention versus the risks of the natural history of a pathological process, whether it is epilepsy, tumor or other, is the proper starting point. The final decision to intervene will in turn be made based on the wide variety of clinical factors that treating clinicians routinely encounter in treating these patients, upon their comfort level with the techniques, the resources available at their institution, and upon the wishes of the patient.

Chicago, IL, USA Richard W. Byrne, M.D.

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