1 Introduction

Stephan Ulmer

Thirty years ago, the very basic idea of fMRI has been introduced by Ogawa using T2∗-weighted images to map changes in blood oxygenation. Since then the technique, paradigms, study designs, and analyzing software have evolved tremendously. Besides its application in basic brain research, it became a very powerful tool in daily clinical routine, especially in presurgical mapping. For the third time, his book focuses on these clinical applications starting from basics and the background, presenting current concepts and their application in a clinical setting.

Understanding brain function and localizing functional areas have ever since been the goal in neuroscience, and fMRI is a very powerful tool to approach this aim. Studies on healthy volunteers usually have a different approach and often a very complex study design, while clinical applications face other problems most commonly related to the limited compliance of the patients. Therefore, the application of fMRI in a clinical setting is a different challenge reflected in the study designs as well as in the analysis of algorithms of the data. Resting-state fMRI will open a new gate in clinical routine. As of now task-related fMRI, i.e., in motor tasks is more robust, but there always have been and will be modifications and improvements. fMRI using ASL might be a new approach. Also, we have learned that it's not a functional area but networks we're dealing with and functional connectivity is important.

Besides the classical definition of functional areas (such as motor- and language-related areas) that might have been shifted through a lesion or could be located in a distorted anatomy prior to neurosurgical resection, further clinical applications are mapping of recovery from stroke or trauma; cortical reorganization, if these areas were affected; and changes during the development of the brain or during the course of a disease. For psychiatric disorders fMRI offers new horizons in understanding the disease. fMRI also helps us to learn about Parkinson's disease and neurodegeneration such as Alzheimer's disease or frontotemporal dementia and changes associated with these diseases. There is also a gap between imaging and clinical findings in multiple sclerosis. Using fMRI, we can monitor functional adaptive or maladaptive reorganization that might help to develop therapeutic strategies. Understanding disorders such as epilepsy, we can now address what fMRI reveals about seizures directly from its onset in the interictal period, through to full clinical expression of the event and eventual termination, although there are technical challenges to do so.

Mapping children represents a twofold challenge. Normative data is not available, and com-

S. Ulmer (✉)
Department of Radiology and Nuclear Medicine, Kantonsspital Winterthur, Winterthur, Switzerland

neurorad.ch, Zurich, Switzerland

Department of Radiology and Neuroradiology, University Hospital Schleswig-Holstein, Kiel, Germany

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pliance is limited. In early childhood or in cognitively impaired children or just simply during brain development, cognitive tasks need to be modified individually, and that again causes problems in analyzing the data and interpreting the results.

Knowledge of basic neuroanatomy and understanding of the electrophysiological background of the fMRI signal, the physiology, and especially the possible pathophysiology of a disease that might affect the results are mandatory. Therefore, we need the results in healthy volunteers to understand the results in patients. In task-related fMRI, we need to monitor the patient in the scanner to guarantee that the results obtained will reflect activation caused by the stimulation, or why there is reduced or even missing activation. While the patient is still in the scanner, a repetition of the measurement can be performed; however, sometimes patients are not capable of performing the task. Here again resting-state fMRI might offer completely new options. A vascular stenosis or the steal effects of a brain tumor or an arteriovenous malformation (AVM) might corrupt the results. There are other sources of disturbance that might influence the results. For us interdisciplinary cooperation was and is the key.

Analyzing data is a science on its own. Fortunately, there is a variety of software solutions available free of charge for the most part. Task-synchronous or singular voluntary head motion during the experiment might corrupt the data to an extent that excludes a reliable interpretation of the data. Better than any available motion correction is avoidance of head movement altogether. As already stated, absence of an expected activation represents a real challenge and raises the question of the reliability of the method per se. Suppression of activation or task-related signal intensity decrease has also not been fully understood. Missing activation in a language task could mislead the neurosurgeon to resect a low-grade lesion close to the inferior frontal lobe and cause speech disturbance or memory loss after resection of a lesion close to the mesial temporal lobe, and therefore – depending on the close cooperation between the clinicians – healthy skepticism and combination with other modalities like direct cortical stimulation might be advisory. Comparison to other modalities of mapping brain functions will also be covered in detail. Again, resting-state fMRI will become more important in presurgical planning.

Prior to the introduction of echo planar imaging, temporal resolution was restricted. Spatial resolution requirements are much more important in individual cases than in a healthy control group, especially in the presurgical definition of the so-called eloquent areas. Higher field strengths might enable us to depict more signals but also more noise in the data as well.

With this book we try to answer some questions and give an overview on how fMRI can be applied for clinical purposes. It is a great honor for me to have this board of experts in the field involved in this project. I hope that you as a reader will enjoy this book as much as I have and that it will help you in your own daily work.