Resting-state Functional Magnetic Resonance Imaging in Presurgical Functional Mapping

Sensorimotor Localization

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KEYWORDS

• Functional MR (fMR) • Resting-state fMR (RS-fMR) • Task fMR (T-MR) • Resting-state networks (RSN) • Multilayer perceptron (MLP) • Sensorimotor network (SMN)

KEY POINTS

- Resting-state functional magnetic resonance (fMR) imaging data for mapping of functional systems is easy to acquire and does not require patient compliance.
- Resting-state fMR imaging offers unique advantages and should be considered as a primary method in patients who are unable to comply with a task paradigm.
- Resting state–derived maps are more extensive than those derived from task fMR imaging.
- Resting-state fMR imaging can localize the sensorimotor cortex reliably and automatically.
- Neurosurgeons and neuroradiologists using task and resting fMR imaging should be aware of their respective advantages and disadvantages.

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INTRODUCTION

The first demonstration of correlated spontaneous fluctuations of the blood oxygenation level–dependent (BOLD) functional magnetic resonance (fMR) imaging signal was reported in1995 by Biswal and colleagues.[1] This phenomenon currently is widely referred to as resting-state functional connectivity.[2,3] The associated topographies are known as resting-state networks (RSNs). Advances in the understanding of resting-state functional connectivity and improved data processing techniques have enabled clinical application of resting-state fMR (RS-fMR) imaging for purposes of presurgical planning.[4–16] RS-fMR imaging is efficient and robust. Nevertheless, the predominant method for presurgical mapping of brain function currently remains task-based fMR (T-fMR) imaging, using paradigms to activate the motor and language systems.

Several studies in normal cohorts have shown that RSNs and T-fMR imaging responses show similar, although not identical, topographies.[17–19] The primary advantage of functional mapping with RS-fMR imaging is that the patients are not required to comply with a task paradigm, although they must rest quietly in the scanner. RS-fMR imaging is compatible with light sedation and even sleep.[20–24] Thus, RS-fMR imaging is feasible in patients who are not candidates for T-fMR imaging, such as in young children and uncooperative or confused adults. Acquisition is simple and requires no specialized equipment or technical skills. For these reasons, use of RS-fMR imaging for presurgical mapping of function is increasing. It is therefore important to compare results obtained by these 2 methods to better understand their relative advantages and disadvantages.

This article compares and contrasts the 2 methods from the technical perspective in a series of patients with brain tumors. It focuses on the differences between the maps of the sensorimotor (SM) system, as seen with T-fMR imaging versus RS-fMR imaging. It uses the anatomic stability of the primary sensory and motor cortex within the precentral and postcentral gyri to compare fMR imaging with anatomic results, which cannot be done with the more variable language system. It also compares our results with similar literature in this area.[25–28]

METHODS

Patients

Patients were recruited from the neurosurgery brain tumor service, initially as part of an National Institutes of Health (NIH)–funded tumor database grant (NIH 5R01NS066905). All aspects of the study were approved by the Washington University (WU) Institutional Review Board. All patients provided informed consent. The following inclusion criteria were used: new diagnosis of primary brain tumor; age more than 18 years; and clinical need for a magnetic resonance (MR) imaging scan, including fMR imaging for presurgical planning as determined by the treating neurosurgeon. In addition, it was required that the patients have both a motor paradigm T-fMR and an RS-fMR imaging scan. Exclusion criteria included prior surgery for brain tumor, inability to have an MR imaging scan, and patients referred from an outside institute with an MR imaging scan not performed at WU. Patient age, sex, and tumor characteristics are listed in **Table 1**.

Acquisition

Patients were scanned with either a Siemens 3T Trio or Skyra scanner (Erlangen, Germany) using a standard clinical presurgical tumor protocol. Anatomic imaging included T1-weighted (T1w) magnetization prepared rapid acquisition gradient echo (MPRAGE), T2-weighted (T2w) fast spin echo, FLAIR imaging, susceptibility-weighted imaging, and precontrast and postcontrast T1w fast spin echo in 3 projections. Specific sequences for presurgical mapping included diffusion tensor imaging for track tracing, T-fMR imaging for motor localization, and RS-fMR imaging.

Both the T-fMR and RS-fMR imaging was acquired using a T2* echo planar imaging sequence (voxel size 3 $\times$ 3 $\times$ 3 mm; echo time = 27 milliseconds; recovery time = 2 seconds; field of view = 256 mm; flip angle = 90°). The motor T-fMR imaging used a block design in which finger tapping was repeated over 4 off/on cycles, each off and on block lasting for 20 seconds (10 frames) for a total of 80 frames (2:40 minutes total per T-fMR imaging run). For most subjects, only 1 motor task session was acquired. For 8 subjects, a second motor task session was acquired, and, for 1 subject, a third task session was acquired. If more than 1 task session was usable, the session providing the maximum overlap index, as defined later, was used for the subsequent overlap analyses. RS-fMR imaging was always acquired as two 6-minute runs (total of 360 frames = 12 minutes).

Preprocessing

Resting-state functional magnetic resonance imaging

Preprocessing of RS-fMR imaging data was performed using previously described