
# Functional Magnetic Resonance Imaging (fMRI)

## Integration into everyday routine

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# Functional Magnetic Resonance Imaging (fMRI)

The interest in functional magnetic resonance imaging has increased considerably in the clinical environment since new CPT® reimbursement codes for pre-surgical planning were introduced in 2007. Siemens offers solutions that allow integration of fMRI techniques into the everyday routine.

### A brief introduction of fMRI

Functional MRI utilizes the magnetic properties of blood to analyze brain activity in specific areas. The technique is based on small changes in blood flow and is referred to as BOLD (Blood Oxygen Level-Dependent) imaging. During this procedure, induced variations in the ratio of oxygenated to deoxygenated blood in localized areas of the brain are imaged to generate fMRI results (Figure A).

### The fMRI procedure

There are three primary steps to an fMRI procedure: preparation, acquisition and processing.

**1. Preparation:**
The patient is given a detailed explanation of the procedure and carefully instructed on the chosen task in order to obtain the highest-quality exam with the least amount of patient-induced motion. It is common to practice these tasks with the patient before the exam to assure the best results.

**2. Acquisition:**
The first step in the acquisition process is to collect routine 3D datasets. These will later be used as the anatomical data upon which the fMRI information will be mapped. Activity in specific regions of the brain is induced and controlled by a set of tasks called a paradigm. These tasks are performed by the patient during the BOLD imaging measurements. Paradigms, some of which are described below, differ based on the area of the brain being examined.

- **Motor Tasks:** The easiest paradigm to implement is a motor task. One version of this paradigm is finger tapping where the patient is asked to touch the thumb of one hand to each of the fingers during the activation portion of the data collection. Motor tasks are often implemented in pre-surgical planning to assess the effects of lesions close to the motor strip and to help improve the surgical outcome.

- **Auditory Tasks:** These tasks can involve rhyming or word generation and may require the patient to speak specific words or phrases during the active portion of the exam. This paradigm allows the clinician to visualize a lesion's proximity and effect on Broca's area, a key area of the brain associated with language, speech and comprehension.

- **Visual paradigms:** Visual paradigms can be implemented when video projection systems are integrated into the examination. This type of paradigm can vary significantly but normally requires the patient to focus on specific images or projections during the examination. Examining the visual cortex in this way provides additional information that can assist the surgeon with minimizing negative surgical effects on vision when removing lesions in this area.

- **Cognitive paradigms:** Cognitive activation paradigms can be very complex and can include stimuli to examine areas of thought and reasoning or even pain and fear. These paradigms are normally confined to the realm of research but offer a clinical benefit in understanding the anatomic areas associated with processes such as learning, memory and decision making.

**3. Processing:**
After data collection, a statistical evaluation (t-test) is used to generate BOLD maps that are combined with routine 3D imaging datasets such as MPRAGE. The combined data can then be used as a neuro-navigational roadmap for use in pre-surgical planning or treatment assessment.

### *syngo*® fMRI

Siemens *syngo* MR applications provide a complete set of tools for fMRI workflow from data acquisition through post-processing. The options available for Siemens portfolio of Tim™ (Total imaging matrix) technology systems include:

**The *syngo* Neuro Suite (Standard)**
This set of protocols (Figure B) and software is standard on all Tim systems. It includes techniques such as single-shot epi as well as MPRAGE used to acquire the anatomic information that will later be fused with the fMRI data.

**Inline BOLD Imaging**
Inline Technology enables the automatic, real-time calculation and display of statistical (t-value) images during the measurement of BOLD paradigms. Observing the data in real-time allows the user to track the progress of the examination and to assure patient cooperation. Motion correction (MoCo) retroactively reduces the relative motion between the data sets measured. Correction is performed through interpolation. It can be selected in advance or as post-processing. This technique is also known as ART (Advanced Retrospective Technique).

The Inline Technology also enables users to stop examinations when an adequate amount of signal has been generated, saving time and improving workflow.

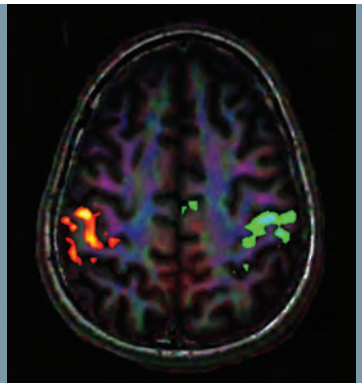

Figure A. Bilateral finger tapping paradigm.

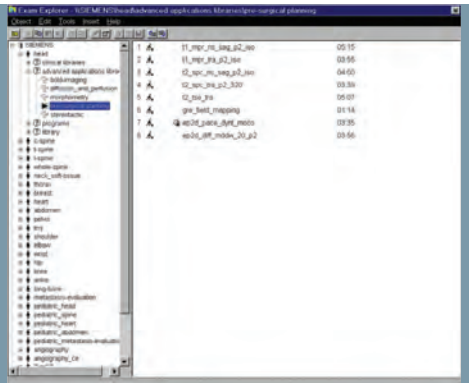

Figure B. The *syngo* Neuro Suite (Standard).

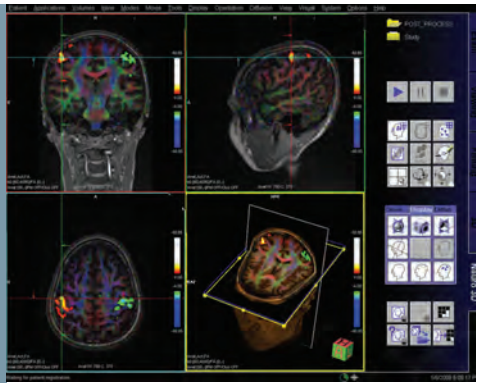

Figure C. *syngo* 3D Neuro Evaluation.

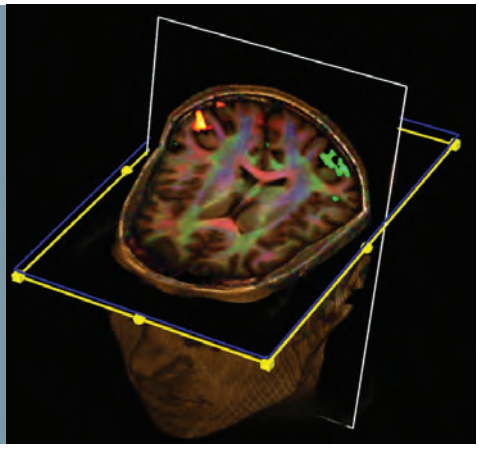

Figure D. fMRI fused with fractional anisotrophy and MPRAGE.

The included sequences and protocols for fMRI acquisition (e.g. motor, visual) need no adjustment and are ready for immediate use. The "mosaic format" can also be enabled to reduce storage space. With Inline BOLD Imaging, functional brain mapping can be optimally integrated into the clinical routine, e.g. prior to neurosurgical interventions.

**_syngo_ 3D PACE**
3D PACE (Prospective Acquisition CorrEction) enhances Inline BOLD imaging with advanced motion correction during the acquisition of a BOLD exam. In contrast to a retrospective motion correction that corrects previously acquired data, the unique 3D PACE tracks the head of the patient, correcting for motion in real time during the acquisition, improving the accuracy of the data collection. Combinable with ART (mentioned above), 3D PACE improves the accuracy of the overlay of fMRI and anatomic data for a more precise fMRI study.

**_syngo_ 3D Neuro Evaluation**
*syngo* 3D Neuro Evaluation shown in Figure C is the comprehensive processing and visualization package for BOLD fMRI. It provides a full set of features for clinical fMRI such as statistical map generation, fused display of fMRI and DTI results, color t-value maps on anatomical datasets, data export to neurosurgical planning and much more. There are also many advanced features for more research-oriented applications.

All of these features can be implemented directly on the main console. This can help improve workflow by avoiding data transfer to fMRI workstations typically designed for research purposes.

Instructions to the patient in the form of a paradigm must be synchronized to the data acquisition. The simplest paradigms utilize voice instructions over the patient intercom. However, third party devices that deliver stimuli synchronized to the data acquisition are available to improve the accuracy of stimulation delivery especially for complex paradigms. Contact your local Siemens Sales representative to discuss the latest third party devices that can be used in conjunction with your system.

**fMRI with the MAGNETOM Verio**
fMRI benefits greatly from the increased signal-to-noise ratio of 3T systems. Siemens MAGNETOM Verio is the first MRI system to offer 3T field strength combined with a 70cm bore and Tim (Total imaging matrix) technology. Figure D demonstrates an fMRI acquisition, taken from the Verio, targeting the motor cortex using a finger-tapping paradigm. The data is combined with diffusion tensor imaging (DTI) and displayed on a 3D dataset to allow the clinician to freely navigate through the results for evaluation or planning.

## Summary
The introduction of CPT reimbursement codes has further fueled the interest in functional magnetic resonance imaging in the clinical setting.

Siemens *syngo* MR applications help meet the increased demand by offering a comprehensive set of sequences, protocols and processing tools, allowing fMRI to be easily integrated into the clinical setting.

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