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The American College of Radiology will periodically define new practice guidelines and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Quality and Safety as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The practice guidelines and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline and technical standard by those entities not providing these services is not authorized.

2007 (Resolution 3)\*

## **ACR–ASNR PRACTICE GUIDELINE FOR THE PERFORMANCE OF FUNCTIONAL MAGNETIC RESONANCE IMAGING OF THE BRAIN (fMRI)**

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### **PREAMBLE**

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

### **I. INTRODUCTION**

This guideline was developed and written collaboratively by the American College of Radiology (ACR) and the American Society of Neuroradiology (ASNR).

Functional magnetic resonance imaging (fMRI) using blood oxygenation level dependent imaging (BOLD) technique is a proven and useful tool for the evaluation of eloquent cortex in relation to a focal brain lesion, such as a neoplasm or vascular malformation. fMRI should be performed only for a valid medical reason.

### **II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL**

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#).

The physician supervising and interpreting fMRI must be clinically informed and understand the specific questions to be answered prior to the procedure in order to plan and perform it safely and effectively. Additionally, physicians performing this procedure should have experience or formal training in performing fMRI.

### III. INDICATIONS

Primary indications for fMRI include, but are not limited to, the following:

- A. Assessment of Intracranial Tumoral Disease
  - 1. Presurgical planning  
Assessment of eloquent cortex (e.g., language, sensory motor, visual) in relation to a tumor.
  - 2. Surgical planning (biopsy or resection).  
Use of fMRI data for surgical guidance or resection procedure.
  - 3. Therapeutic follow-up  
Evaluation of preserved eloquent cortex.
- B. Assessment of Language Functions for Epilepsy Surgery.

### IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) and the ACR Guidance Document for Safe MR Practices (2007).

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis.

### V. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The supervising physician must also understand the pulse sequences to be employed and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

The written or electronic request for fMRI should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including

known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35, adopted in 2006)

#### A. Patient Selection

The physician responsible for the examination shall supervise patient selection and preparation, and be available in person or by phone for consultation. Patients shall be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment.

Certain indications require the administration of intravenous (IV) contrast media as part of the diagnostic MRI procedure. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. (See the [ACR Practice Guideline for the Use of Intravascular Contrast Media](#).)

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may be needed to achieve a successful examination. If moderate sedation is necessary, refer to the [ACR-SIR Practice Guideline for Sedation/Analgesia](#).

#### B. Facility Requirements

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

#### C. Examination Technique

##### 1. Prescanning

Discussion with the referring physician to determine the appropriate type of fMRI task to be performed needs to take place prior to the

study. Also the patient's ability to comply with the task should be evaluated.

## 2. Scanning procedure

fMRI imaging is typically performed using an echo planar gradient echo (EPI) pulse sequence or asymmetrical spin echo pulse sequence. The following imaging parameters may be used as a guide: matrix size = 64\*64; TR = 2-3 sec; FOV = 22 cm; slices = 24 (whole brain); slice thickness = 4 to 5 mm. The imaging is typically performed using the well established block design although an event related design could be used. In a block design study the subjects will be presented with 6 separate blocks of activation conditions alternating with 6 rest period blocks. During each block (30 sec long), 10 volumes of EPI images are acquired, yielding a total of 120 EPI volumes. The patients may be asked to perform one or more of the following tasks: sequential movement of finger-to-thumb, hand squeeze using both the dominant and non-dominant hands, language function, visual testing. Imaging can be performed with an MRI scanner having a 1.5 Tesla or higher field strength, depending on availability, and using a head coil with one or more channels. Use of head coil with higher number channels is recommended if available for improved signal to noise ratio (SNR). Performing a cine loop visual evaluation of all the EPI volumes is recommended to look for gross motion of the images prior to postprocessing. Documentation of patient compliance with the tasks conducted is necessary after the study.

### D. Postprocedure Processing

The fMRI images should be postprocessed using programs readily available. Initially a 3D automated image registration routine (6-parameter rigid body, sinc interpolation; second order adjustment for movement) or other valid algorithms should be applied to the EPI volumes to realign them with the first volume of the first series used as a spatial reference. Typically misregistration of voxels less than 2 to 3 mm is considered acceptable for further analysis. Next, all volumes should be spatially smoothed using convolution with a Gaussian kernel of 8 cubic mm full width at half maximum, to increase the signal-to-noise ratio and account for residual intersession differences. Next individual subject-level statistical analyses should be performed using the general linear model or other acceptable models. The scans corresponding to the activation condition and the baseline conditions are later

modeled using a canonical hemodynamic response function.

Contrast maps are obtained through the following two linear contrasts of event types: activation vs. baseline. A significant threshold based on spatial extent and cluster probability based on the discretion of the radiologist should be applied to the contrast maps to show statistically significant areas of activation. As a general guide the statistical parameters for creating significant activation maps in the motor cortex are as follows: Cluster spatial extent <10, and statistical threshold  $p < 0.05$ . Based on these contrasts, statistical parametric maps are typically created for visual representation of the areas in the brain where statistically significant differences in BOLD contrasts between the activation and rest are present. These statistical maps can be overlaid onto the patient's anatomical images for better delineation of the tumor or other lesion margins and location of the activation regions. Color values representing different statistical thresholds are also typically assigned to these final postprocessed fMRI images.

## VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

## VII. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance shall meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

## VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR web page (<http://www.acr.org/guidelines>).

Specific policies and procedures related to MRI safety should be in place along with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards

associated with the MRI examination of the patient as well as to others in the immediate area. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination.

Equipment monitoring should be in accordance with the [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging \(MRI\) Equipment](#).

## ACKNOWLEDGEMENTS

This guideline was revised according to the process described under the heading *The Process for Developing ACR Practice Guidelines and Technical Standards* on the ACR web page (<http://www.acr.org/guidelines>) by the ACR Guidelines and Standards Committee of the Commission on Neuroradiology in collaboration with the ASNR.

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**Suggested Reading** (Additional articles that are not cited in the document but that the committee recommends for further reading on this topic)

1. Kanal E, Borgstede JP, Barkovich AJ, et al. ACR guidance document for safe MR practices. *AJR* 2007;188:1-27.
2. Hirsch J, Ruge MI, Kim KH, et al. An integrated functional magnetic resonance imaging procedure for preoperative mapping of cortical areas associated with tactile, motor, language, and visual functions. *Neurosurgery* 2000;47:711-721.
3. Lee CC, Ward HA, Sharbrough FW, et al. Assessment of functional MR imaging in neurosurgical planning. *AJNR* 1999;20:1511-1519.
4. Medina LS, Aguirre E, Bernal B, Altman NR. Functional MR imaging versus Wada test for evaluation of language lateralization: cost analysis. *Radiology* 2004;230:49-54.
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6. Tomczak RJ, Wunderlich AP, Wang Y, et al. fMRI for preoperative neurosurgical mapping of motor cortex and language in a clinical setting. *J Comput Assist Tomogr* 2000;24:927-934.
7. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants, and Devices*. 2005 edition. Los Angeles, Calif: Biomedical Research Publishing; 2005.
8. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology* 2004;232:635-652.

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\*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Guideline  
2007 (Resolution 3)