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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.

Revised 2009 (Resolution 10)\*

## **ACR TECHNICAL STANDARD FOR DIAGNOSTIC MEDICAL PHYSICS PERFORMANCE MONITORING OF MAGNETIC RESONANCE IMAGING (MRI) EQUIPMENT**

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### **PREAMBLE**

These standards 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 standards 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 standards, 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 standards 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 standards. However, a practitioner who employs an approach substantially different from these standards 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 standards 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 standards is to assist practitioners in achieving this objective.

### **I. INTRODUCTION**

The performance of all magnetic resonance imaging (MRI) units should be evaluated upon installation and at least annually to ensure proper functioning. Additional or more frequent performance monitoring may be necessary in certain situations (e.g., after major equipment maintenance). Although it is not possible to consider all possible variations of equipment to be monitored, adherence to this standard will promote high image quality.

### **II. GOAL**

The goal is to establish performance standards to promote production of high-quality diagnostic MR images that are consistent with the clinical use of MRI equipment and with the clinical objectives of examinations.

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

The personnel qualified to carry out acceptance testing and monitoring of MRI equipment for the purposes of this standard include a Qualified Medical Physicist or a Qualified MR Scientist.

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The American College of Radiology (ACR) considers certification and continuing education and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

The appropriate subfield(s) of medical physics for this standard are Diagnostic Radiological Physics and Radiological Physics.

A Qualified MR Scientist is an individual who has obtained a graduate degree in a physical science involving nuclear MR or MRI. He or she should have 3 years of documented experience in a clinical MRI environment.

A Qualified Medical Physicist should meet the [ACR Practice Guideline for Continuing Medical Education \(CME\)](#). (ACR Resolution 17, 1996 – revised in 2008, Resolution 7)

Regardless of certification status, to be considered a Qualified Medical Physicist one should have performed evaluations of at least 6 MRI systems under the direction of a Qualified Medical Physicist or MR Scientist.

The medical physicist/MR scientist must be familiar with the principles of MRI safety for patients, personnel, and the public; the Food and Drug Administration guidance for MRI diagnostic devices; and other regulations pertaining to the performance of the equipment being monitored. The medical physicist/MR scientist shall be knowledgeable in the field of nuclear MR physics and familiar with MRI technology, including the function, clinical uses, and performance specifications of MRI equipment, as well as calibration processes and limitations of the performance testing hardware, procedures, and algorithms. The medical physicist/MR scientist shall have a working understanding of clinical imaging protocols and methods of their optimization. This proficiency shall be maintained by participation in continuing education programs of sufficient frequency to ensure familiarity with current concepts, equipment, and procedures.

The medical physicist/MR scientist may be assisted in obtaining test data for performance monitoring by other properly trained individuals. These individuals must be properly trained and approved by the medical physicist/MR scientist in the techniques of performing the tests, the function and limitations of the imaging

equipment and test instruments, the reason for the tests, and the importance of the test results. The medical physicist/MR scientist must review and approve all measurements.

#### **IV. PERFORMANCE CHARACTERISTICS TO BE MONITORED**

##### **A. Performance Evaluation**

The performance of each MRI unit should be evaluated at least annually. This evaluation should include, but not be limited to, the following tests:

1. Magnetic field homogeneity.
2. Slice position accuracy.
3. Slice thickness accuracy.
4. Radiofrequency (RF) calibration for all coils.
  - a. Frequency and gain/attenuator verification (prescan values).
  - b. Image signal-to-noise ratio (SNR) for all coils.
  - c. Intensity uniformity for all volume coils.
  - d. Phase stability and image artifact assessment for all coils.
5. Softcopy (monitor) fidelity.
6. Evaluation of quality control (QC) program.

The annual performance evaluation must also include an assessment of the MRI safety program (signage, access control, screening procedures, and cryogen safety) as well as an inspection of the physical and mechanical integrity of the system.

##### **B. Quality Control Program**

A continuous QC program shall be implemented for all MRI units. The program should be established with the assistance of a medical physicist/MR scientist. The minimum number of tests and testing frequency should include, but not be limited to, those specified by the ACR MRI Quality Control Manual. The medical physicist/MR scientist should identify the person responsible for performing the tests and may choose to increase the frequency of testing based on the facility and MRI usage. The QC program should include, but not be limited to, the following:

1. Setup and positioning accuracy (mechanical inspection).
2. Central frequency.
3. Transmitter gain or attenuation (head coil RF calibration).
4. Geometric accuracy (gradient calibration).
5. High-contrast spatial resolution.
6. Low-contrast detectability.
7. Image artifact assessment.
8. Film processor QC.
9. Hardcopy fidelity.

10. Softcopy fidelity.
11. Visual checklist.

For those systems with magnetic resonance spectroscopy (MRS) capabilities, establishment of an MRS quality control program should be considered. Water and metabolic peak areas, full width at half maximum, baseline noise, and volume-of-interest accuracy should be assessed.

If any QC parameter being monitored falls outside of the control limits, corrective action should be taken. A medical physicist/MR scientist should be available to assist in prescribing corrective actions for unresolved problems.

A medical physicist/MR scientist should periodically monitor the results of the QC program.

#### C. Acceptance Testing

Initial performance testing should be performed upon installation. This testing or oversight of testing should be more comprehensive than periodic performance testing and should be consistent with current acceptance testing practices. The acceptance testing protocol should include an evaluation of all coils.

#### D. Written Survey Reports and Follow-up Procedures

The medical physicist/MR scientist shall provide a written report of the findings of acceptance testing and performance evaluation to responsible physician(s) and to the professional(s) responsible for servicing of the MRI equipment. If appropriate, the medical physicist/MR scientist should initiate the required service. Written reports shall be provided in a timely manner consistent with the importance of any adverse findings.

If use of the equipment poses imminent danger to patients or staff, the medical physicists/MR scientist must take immediate action to preclude use of the equipment.

### ACKNOWLEDGEMENTS

This standard 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 Guidelines and Standards Committee of the Commission on Medical Physics.

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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. *Acoustic Noise Measurement Procedure for Diagnostic Magnetic Resonance Imaging Devices*. Rosslyn, Va: National Electrical Manufacturers Association; 2006. MR Standards MS4.
2. *Characterization of Special Purpose Coils for Diagnostic Magnetic Resonance Images*. Rosslyn, Va.: National Electrical Manufacturers Association; 2000. MR Standards MS6.
3. *Determination of Gradient-Induced Electric Fields in Diagnostic Magnetic Resonance Imaging*. Rosslyn, Va.: National Electrical Manufacturers Association; 2006. MR Standards MS11.
4. *Determination of Image Uniformity in Diagnostic Magnetic Resonance Images*. Rosslyn, Va.: National Electrical Manufacturers Association; 2008. MR Standards MS3.
5. *Determination of local specific absorption rate (SAR) in diagnostic magnetic resonance imaging*. Rosslyn, Va: National Electrical Manufacturers Association; 2006. MS10.
6. *Determination of Signal-to-Noise Ratio (SNR) in Diagnostic Magnetic Resonance Imaging*. Rosslyn, Va.: National Electrical Manufacturers Association; 2008. MR Standards MS1.
7. *Determination of Slice Thickness in Diagnostic Magnetic Resonance Imaging*. Rosslyn, Va.: National Electrical Manufacturers Association; 2003. MR Standards MS5.
8. *Determination of Two-Dimensional Geometric Distortion in Diagnostic Magnetic Resonance Images*. Rosslyn, Va: National Electrical Manufacturers Association; 2003. MR Standards MS2.
9. *Measurement Procedure for Time Varying Gradient Fields (dB/dt) for Magnetic Resonance Imaging Systems*. Rosslyn, Va.: National Electrical Manufacturers Association; 1993. MR Standards MS7.
10. *MRI Quality Control Manual*. Reston, Va.: American College of Radiology; 2004.
11. The safe use of equipment in the magnetic resonance environment. *Health Devices* 2001;30:421-444.

12. Drost DJ, Riddle WR, Clarke GD. Proton magnetic resonance spectroscopy in the brain: report of AAPM MR Task Group #9. *Med Phys* 2002;29:2177-2197.
13. Gardner EA, Ellis JH, Hyde RJ, Aisen AM, Quint DJ, Carson PL. Detection of degradation of magnetic resonance (MR) images: comparison of an automated MR image-quality analysis system with trained human observers. *Acad Radiol* 1995;2:277-281.
14. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document for safe MR practices: 2007. *AJR* 2007;188:1447-1474.
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17. Och JG, Clarke GD, Sobol WT, Rosen CW, Mun SK. Acceptance testing of magnetic resonance imaging systems: report of AAPM Nuclear Magnetic Resonance Task Group No. 6. *Med Phys* 1992;19:217-229.

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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 Standard

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