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ACR–AAPM TECHNICAL STANDARD FOR DIAGNOSTIC MEDICAL PHYSICS PERFORMANCE MONITORING OF MAGNETIC RESONANCE (MR) IMAGING EQUIPMENT

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and 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 the guidance in this document 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 purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

This technical standard was revised collaboratively by the American College of Radiology (ACR) and the American Association of Physicists in Medicine (AAPM).

The performance of all magnetic resonance (MR) imaging units should be evaluated upon installation and at least annually to ensure proper functioning [1]. Additional or more frequent performance monitoring may be necessary in certain situations (eg, after major equipment repairs or upgrades). Although it is not possible to consider all possible variations of equipment to be monitored, adherence to this technical standard will encourage MR facilities to strive for, achieve, and maintain a high level of diagnostic image quality.

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

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A Qualified Medical Physicist or a Qualified MR Scientist must carry out acceptance testing and monitoring of MR imaging equipment.

A Qualified Medical Physicist or Qualified MR Scientist 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, 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 or Qualified MR Scientist. The ACR strongly 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, the American Board of Science in Nuclear Medicine (ABSNM), or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist or Qualified MR Scientist should meet the ACR Practice Parameter for Continuing Medical Education (CME). [2]

The appropriate subfield of medical physics for this technical standard is Diagnostic Medical Physics (including medical physics certification categories of Radiological Physics, Diagnostic Radiological Physics, or Diagnostic Imaging Physics). (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022, Resolution 41f)

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

Regardless of certification status, to be considered a Qualified Medical Physicist or MR Scientist one should have performed evaluations of at least three MR systems in accordance with the ACR MRI Quality Control Manual under the direction of a Qualified Medical Physicist or MR Scientist. Additional guidance on the initial qualifications, as well as continuing experience and education for the Qualified Medical Physicist or MR Scientist, is provided in the current documents “ACR MRI Accreditation Program Requirements” and “Accreditation Program Requirements and FAQs for Medical Physicists/MR Scientists,” which can be found at https://www.acraccreditation.org/modalities.

The Qualified Medical Physicist or MR Scientist must be familiar with the principles of MR safety for patients, personnel, and the public [4]; the Food and Drug Administration (FDA) guidance for MR diagnostic devices; and other regulations pertaining to the performance of the equipment being monitored. The Qualified Medical Physicist or MR Scientist must be knowledgeable in the field of MR physics and familiar with MR technology, including the function, clinical uses, and performance specifications of MR imaging equipment, as well as calibration processes and limitations of the performance testing hardware, procedures, and algorithms. The Qualified Medical Physicist

or MR Scientist must have a working understanding of clinical imaging protocols and methods of their optimization. This proficiency should be maintained by participation in continuing education programs of sufficient frequency to ensure familiarity with current concepts, equipment, and procedures.

The Qualified Medical Physicist or MR Scientist is responsible for the test protocols, the test methods, and the acceptability criteria. The Qualified Medical Physicist or MR Scientist may be assisted by properly trained individuals in obtaining data in accordance with applicable regulations. A Qualified Medical Physicist or MR Scientist is responsible for determining whether the assisting individual is in the techniques of performing tests, the function and limitations of the imaging equipment and test instruments, the reason for the tests, the importance of the test results, and any other skills or knowledge needed to safely perform the work. The assisting individual must be under the direct supervision[2] of the Qualified Medical Physicist or MR Scientist during initial and annual surveys. The Qualified Medical Physicist or MR Scientist is responsible for all surveys and must review, interpret, and approve all data as well as provide a signed report with conclusions and any recommended follow-up actions [5,6].

III. PERFORMANCE CHARACTERISTICS TO BE MONITORED

A. Acceptance Testing

Initial MR imaging equipment performance evaluation must be conducted upon installation of the MR imaging scanner and after major upgrades. This evaluation should be more comprehensive than periodic evaluation and should be consistent with current MR imaging equipment performance acceptance evaluation practices [1,4]. The acceptance evaluation protocol should include a quantitative assessment of all coils. All new or replacement coils should be evaluated prior to clinical use. The initial MR Safety program must be established prior to clinical use with the assistance of the Qualified Medical Physicist or MR Scientist. This program should include implementation of site access restrictions (MR Safety Zones) as well as MR Safety screening of patients and personnel. The initial MR Safety program should be reviewed periodically for relevance, applicability, and continuous improvement.

Prior to the initial MR imaging equipment performance evaluation, electrical safety and digital image communication must be verified by appropriate personnel.

The initial MR imaging equipment performance evaluation should be performed by a Qualified Medical Physicist or MR Scientist and should be completed before clinical use.

Acceptance tests must include:

1. Compliance with relevant regulatory requirements
2. Compliance with all terms and line items of the purchase agreement or contract
3. Compliance with manufacturer's relevant imaging and safety performance specifications
4. Evaluation of shielding (eg, static magnetic field shielding, radiofrequency [RF] shielding)
5. Tests performed during the annual performance evaluation

B. Performance Evaluation

The performance of each MR system must be evaluated at least annually. At a minimum this evaluation should include the following items or their equivalents:

1. Magnetic field homogeneity
2. Slice position accuracy
3. Slice thickness accuracy [7]
4. Performance evaluation for coils used clinically

[2] For the purpose of this standard, direct supervision means that the Qualified Medical Physicist or MR Scientist must be present and immediately available to furnish assistance and direction throughout the performance of the survey. It does not mean that the Qualified Medical Physicist or MR Scientist must be present in the room where the procedure is performed.

a. Coil physical visual inspection
b. Transmitter gain/attenuator verification
c. Image signal-to-noise ratio (SNR) [8-10]
d. Image artifact assessment
e. Image intensity uniformity for all volume coils [11]
f. Year-to-year variations of each of the above parameters should be tracked

5. Geometric accuracy (gradient calibration) [10]
6. High-contrast spatial resolution
7. Low-contrast detectability
8. Acquisition workstation monitor performance
9. Inspection of the physical and mechanical integrity of the system
10. Evaluation of technologist quality control (QC) program
11. Assessment of the MR imaging safety program [4]

C. QC Program

A continuous QC program must be implemented for all MR imaging systems. The program should be established with the assistance of a Qualified Medical Physicist or MR Scientist. The Qualified Medical Physicist or MR Scientist should verify the person(s) responsible for performing the tests and may recommend increasing the frequency of testing based on the facility and MR imaging usage. The minimum number of tests and testing frequency are specified in the ACR MRI Quality Control Manual [12]. At minimum, the QC program should include the following items or their equivalents:

1. Image artifact assessment
2. Central frequency
3. Transmitter gain or attenuation (head coil RF calibration)
4. Setup and positioning accuracy (mechanical inspection)
5. Geometric accuracy (gradient calibration) [10]
6. High-contrast spatial resolution
7. Low-contrast detectability (eg, SNR)
8. Acquisition workstation monitor quality control
9. Visual checklist
10. If a film printer is used, film printer fidelity when used for primary interpretation

For MR systems performing advanced MR techniques, a QC program relevant to the advanced imaging technique should be established [1,13]

If any monitored QC parameter falls outside of the control limits, corrective action must be considered. A Qualified Medical Physicist or MR Scientist should be consulted regarding corrective actions for unresolved problems.

D. Written Survey Reports and Follow-up Procedures

The Qualified Medical Physicist or MR Scientist must provide a written report of the findings of acceptance testing and performance evaluation to the professional(s) in charge of obtaining or providing necessary service to the equipment and, if appropriate, to the responsible physician(s). Written reports must be provided in a timely manner consistent with the importance of any adverse findings.

If appropriate, the Qualified Medical Physicist or MR Scientist should notify the facility to initiate the required service. The facility must complete corrective actions in a timely manner consistent with the importance of any adverse findings. The facility should retain service reports from competent service personnel as verification that the issue(s) were appropriately resolved. The reports may be reviewed by a Qualified Medical Physicist or MR Scientist to confirm that the equipment is performing in a safe and acceptable fashion after the required service is performed or as required by federal, state, or local regulations.

If use of the equipment would pose a danger to life or health or potentially result in erroneous clinical findings, the Qualified Medical Physicist or MR Scientist in collaboration with the facility's Radiation or MR Safety Officer and interpreting physician must take immediate action to either prevent equipment use or to indicate in writing what limited studies can be performed safely using the equipment until the hazard is addressed.

IV. MR IMAGING SAFETY

The MR Medical Director should oversee, or designate a qualified individual to oversee, the MR imaging safety program for employees, patients, and other individuals in the surrounding area [4]. The MR Medical Director should ensure that records concerning QC, safety, and protection are properly maintained and updated in the MR imaging quality assurance (QA) procedures manual. The Qualified Medical Physicist or MR Scientist should review these records at least annually.

To minimize risks in the MR environment to patients, health care professionals, and any others that may encounter the fields of the MR scanner, each facility must establish, implement, and maintain current safety policies and procedures. Information regarding establishment of a quality MR Safety program can be found in the ACR Guidance Document on MR Safe Practices: 2013 and the ACR MRI Quality Control Manual [4,12,14].

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*As of May 2015, all practice parameters and technical standards that are collaborative with only the American Association of Physics in Medicine are approved by the ACR Council Steering Committee and the ACR Board of Chancellors and will not go through the ACR Council (ACR Resolution 54, 2015). The effective date is the first day of the month following a 60-day period that begins on the date the document was approved.

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