ACR–AAPM TECHNICAL STANDARD FOR MEDICAL PHYSICS PERFORMANCE MONITORING OF PET/MRI EQUIPMENT

The American College of Radiology, with more than 40,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

The American College of Radiology will periodically define new practice parameters 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 parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter 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 and approval. The practice parameters 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 parameter and technical standard by those entities not providing these services is not authorized.

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.

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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 developed collaboratively by individuals with recognized expertise in medical physics, representing the American College of Radiology (ACR) and the American Association of Physicists in Medicine (AAPM).

The performance of a hybrid PET/MRI system must be evaluated upon installation to verify compliance with manufacturer specifications and federal and local regulations. It must also be monitored periodically, the frequency depending on the complexity and intended use of the equipment.

Monitoring should be done at least annually, or more frequently if required by state or local regulatory agencies,

by a Qualified Medical Physicist to ensure the system is functioning properly and maintaining the highest standards of patient safety. Additional or more frequent monitoring may be necessary after repair or service (see section IV.B) that could affect system performance, image quality, or patients or staff safety.

Although it is not feasible to address all possible variations of equipment performance, adherence to this technical standard will help optimize image quality and patient safety. Key considerations include system performance characteristics, radiation and MR safety, personnel qualifications, and follow-up procedures.

The goals of this standard are:

1. To ensure the production of optimal-quality diagnostic images consistent with the clinical use of the equipment and the information requirements of the examination; and
2. To evaluate system performance and verify adherence to manufacturer specifications and regulatory requirements at acceptance and during periodic constancy testing.

This technical standard for hybrid PET/MRI systems is aligned with the ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of PET/CT Imaging Equipment and the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance (MR) Imaging Equipment [1, 2]. In this context, acceptance testing, equipment performance evaluation, and continuous QC tests follow paradigms similar to those used for standalone PET/CT and MRI systems, with the exception of elements unique to hybrid PET/MRI systems. Additional complexities do exist in the use of hybrid PET/MRI systems when compared to two separate standalone devices, particularly in aspects related to image quality and patient safety.

II. QUALITY MANAGEMENT

Quality Management (QM) is, "an overall management system that includes establishing quality policies and quality objectives, and processes to achieve quality objectives through quality planning, quality assurance (QA), quality control (QC), and quality improvement." [3]

II. QUALITY MANAGEMENT

A. Quality Management Team

The QM team is composed of the individuals who are responsible for, and involved with, the technical aspects of clinical use of PET/MRI equipment. A QM team is composed of physician(s), Qualified Medical Physicist(s), and technologist(s). In general, one physician will act as the supervising physician responsible for the overall quality and safety of the clinical operation of PET/MRI equipment. The Qualified Medical Physicist is responsible for and has oversight of equipment testing; protocol design, review, and optimization; and criteria for action. Technologists are responsible for the routine operation of the PET/MRI equipment. As such, the QM team should be led or overseen by the supervising physician with support from the Qualified Medical Physicists on equipment issues, and technologists on imaging workflow and daily systems operations. Most commonly, the Qualified Medical Physicist and technologist roles include either multi-specialty individuals or two single-specialty individuals (i.e., one specializing in MRI and the other in PET). While different types of physicians (e.g., radiologists, nuclear medicine physicians) may be involved in PET/MRI examinations, the participation of all physicians on a QM team is likely unnecessary. At least one physician, with appropriate expertise in PET and MRI, should participate in the QM team to provide input on quality processes from both physician and end-user perspectives.

For the purposes of this Technical Standard, the qualifications and duties of a Qualified Medical Physicist for the MRI subsystem can be replaced by those of an MR Scientist (see section V.A) (3197639).

The QM team should communicate at regular intervals (eg, monthly, quarterly, semiannually, or annually) to review issues, discuss upcoming activities, and perform a general review of past QA and QC results. In addition, such correspondence provides an opportunity to discuss any necessary updates to the QM practices and procedures discussed later in this section.

The QM team should provide input on purchasing decisions for new or replacement equipment and associated

accessory hardware and software. A consistent QM approach to hardware and software simplifies the requirements associated with the ongoing QA and QC measures.

As described in *Qualifications and Responsibilities of Personnel*, the Qualified Medical Physicists may be assisted by Medical Physics Assistants (MPAs) (as described in section V.D) in the collection of data, subject to all applicable regulations and relevant guidance. The Qualified Medical Physicists and the QM team should define the required training and approval process for MPAs under the supervision of a Qualified Medical Physicist for MPAs. This Technical Standard recommends that all annual and continuous QC testing be performed either by or under thesupervision of the Qualified Medical Physicists. In the scenario of two single-specialty Qualified Medical Physicists, each may individually define and oversee testing of the independent modality subsystem elements of the PET/MRI scanner, but are required to collaborate on testing of joint functionality. Also in this scenario, each Qualified Medical Physicist is responsible for ensuring that all members of the alternate team undergo appropriate safety training and considerations for any factors they may be exposed to during their activities; for example, MRI safety training for the PET team and radiation safety training for the MRI team.

II. QUALITY MANAGEMENT

B. Service Records

Equipment and relevant software calibrations should be performed as defined by the equipment manufacturer. Some manufacturers require calibrations to be performed by technologists or other clinical personnel, while other manufacturers describe calibrations as part of routine or corrective service. Similarly, some technical configurations may be required to be done by service engineers, especially at installation, while other configurations may be appropriately adjusted by technologists or medical physicists. For all equipment and relevant software, regular preventive maintenance and corrective service should be performed, documented, and records retained by a service engineer, following the maintenance schedule recommended by the manufacturer. Copies of all service records, including corrective actions, must be shared with, and retained by, the clinic providing patient care. The QM team should, at minimum, have access to these records, and if sensible in the context of facility culture and operational practices, it may be best for the QM team to keep and manage these records.
A review of service records in conjunction with annual system testing is recommended to provide context to any observed and reported QA and QC metric deviations.

II. QUALITY MANAGEMENT

C. Records of Devices and Tools

QM of PET/MRI equipment requires accurate and complete installation records of the equipment. At a minimum, the QM team should establish an asset management methodology to track the location, manufacturer, model, date of manufacture and unique identifier (e.g., serial number) of all devices in their purview. The asset management system should serve as either the repository for or the link to permanent storage for quality performance records and reports.

In addition to the PET/MRI system itself, the QM team should maintain accurate records of the tools used to perform QC tests, as applicable. These records should include tool description or type, manufacturer, model, date of manufacture, software versions, and unique identifier. The calibration, calibration schedule, maintenance history, and intercomparison history, as well as the schedule of the applicable tools, should be kept with these records to ensure regulatory and policy compliance.

These records should include detailed information on both manufacturer-supplied tools and customer-owned tools (e.g., QA phantoms, monitoring equipment, ancillary devices). Ensuring compatibility between customer and manufacturer tools is essential to avoid performance issues and ensure reliable QC results. The manufacturer is responsible for clearly documenting tool requirements, providing validation data, and notifying customers of any compatibility updates or tool revisions. In turn, customers must track tool usage, adhere to calibration schedules, and ensure all devices meet the specifications outlined by the manufacturer. The QM team should include a review of the asset management system as part of its regular meetings. Individual members of the team should be assigned specific data points of interest to oversee. The more detailed and automated the asset management system, the easier the delineation of the data for QM team members.

These comprehensive records support regulatory compliance, facilitate troubleshooting, and enable consistent system performance through traceable, well-documented QA practices.

II. QUALITY MANAGEMENT

D. Policies (as applicable)

Effective QM requires a comprehensive set of policies and guidelines to address all aspects of equipment performance. These policies and guidelines should, at a minimum, adhere to state and federal regulations, as well as recommendations of accreditation bodies where applicable. This subsection lists those aspects of PET/MRI equipment that should be included in such documentation.

1. Acceptable equipment performance standards, ranges, and limits
2. Expectations for installation or configurations
3. Summary of QA and QC frequencies
4. Reporting of QA and QC results
5. Review of applicable regulatory and accreditation requirements
6. Vendor preventative maintenance schedule
7. Requirements for postservice
8. Personnel roles
9. User and operator responsibilities
10. MRI- and PET-specific safety considerations

It is recommended that these policies and guidelines include at a minimum all elements of the MRI and PET subsystem documents; see the following for additional details:

- ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of PET/CT Imaging Equipment [2]
- ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance (MR) Imaging Equipment [1]

II. QUALITY MANAGEMENT

E. Reporting Structure for Findings

To ensure the efficient resolution of PET/MRI system issues, a well-defined reporting and support structure is essential. Technologists or QC team members serve as the first line of detection and should promptly document any issues, including specific error messages, observed system behavior, and the impact on workflow or patient care. These details should then be reported to the appropriate local support team, such as the Qualified Medical Physicist, IT department or designated service contact, in accordance with institutional protocols.

It is the responsibility of the customer (e.g., hospital or clinic) to ensure that local support channels are clearly established and equipped to manage initial troubleshooting. Issues that remain unresolved must be escalated to the manufacturer's support team through the designated communication channels, accompanied by the initial documentation and a summary of steps already taken.

Manufacturers, in turn, must provide accessible and responsive support services, including well-defined escalation pathways, comprehensive documentation for common issues and timely on-site or remote assistance. They should also actively track reported issues to identify recurring patterns, and implement preventative solutions through software updates, hardware modifications and proactive customer communication.

III. QUALITY ASSURANCE

Quality assurance is, "a component of QM focused on providing confidence that quality requirements will be fulfilled; it includes all activities (planned, systematic, and practice-based activities) that demonstrate the level of quality achieved by the output of a process.” [3]

Routine QA activities include assessment of imaging protocols, scanner performance and measurement accuracy

to support high-quality clinical and research applications. Adherence to robust QA practices helps minimize variability, optimize image quality, and ensure patient and staff safety.

III. QUALITY ASSURANCE

A. Periodic Review of Settings/Protocols/Clinical Outputs

The Qualified Medical Physicist should review the routine QC results at least annually and report any findings or recommendations to the QM team. The QC targets and test frequencies at a site should be adjusted accordingly with advancements or changes in best clinical practice. For PET/MRI systems that are not explicitly addressed by existing guidelines, such as those based on newly developed technologies, the Qualified Medical Physicist should work with the supervising physician, technologists, and vendor documentation to develop appropriate, site-specific QA tests and testing intervals. This tailored approach ensures that even nonstandard systems are assessed rigorously to maintain image quality and patient safety.

Periodic review of PET/MRI scanning protocols, system settings, and clinical image quality should be carried out collaboratively by the Qualified Medical Physicist, radiologists, technologists, and other relevant clinical personnel. The review process should include a thorough evaluation of scanner configuration, acquisition parameters, reconstruction algorithms, clinically-relevant artifacts, and compliance with institutional safety guidelines, practices, and policies. Updates to imaging protocols can be made to reflect changes in clinical practice, major upgrades, and improved processing techniques. However, these updates must always comply with regulatory requirements.

An important consideration in QA is awareness of potential PET artifacts in clinical cases related to MRI-based attenuation correction, which are not seen in scanner performance testing with phantoms [4]. The QA program should include continuous education for physicians, technologists, and physicists, as well as internal review of clinical artifacts encountered.

III. QUALITY ASSURANCE

B. Calibration of Measurement Devices/Tools

Measurement devices should be regularly calibrated or cross-referenced with calibrated devices to ensure the quality of their readings. This process applies to devices including, but not limited to:

- Dose calibrator
- Well counter
- Radiation survey meter (eg, Geiger-Mueller Meter)
- Photometer
- Thermometer
- Hydrometer
- Gauss meter

The Qualified Medical Physicist must ensure that all calibration procedures are based on established professional practice guidelines and that they meet applicable regulatory requirements. Calibration should be performed regularly, and any instruments used in QC testing must be cross-referenced with known standards or calibration sources.

Where available, automated correction algorithms and artificial intelligence (AI)-driven QA tools can be integrated into workflows to enhance consistency and long-term system reliability. These tools can provide real-time assessment, highlight deviations and support trend analysis — ultimately improving the effectiveness of QA programs in hybrid PET/MRI environments.

IV. QUALITY CONTROL

Quality Control is, "a component of QM focused on the fulfillment of quality requirements; it includes activities that impose specific quality on a process; and entails the evaluation of actual operating performance characteristics of a device or system, comparing it to desired goals, and acting on the difference; QC works on the input to a process to ensure that important elements or parameters specific to the process are correct." [3]

Equipment performance must be evaluated upon installation and monitored at least annually by a Qualified Medical Physicist to ensure proper functioning within defined performance criteria. Additional or more frequent performance monitoring may be necessary in certain situations (e.g., following major equipment maintenance). Although it is not possible to consider all variations in equipment performance that may require monitoring, adherence to this Technical Standard will help optimize image quality and support consistent equipment performance in clinical use. Key points to consider are performance characteristics to be monitored, estimated patient radiation dose, qualifications of personnel, and follow-up procedures.

A documented QC program with procedure manuals, records, and outcomes of interventions, in either soft or hard copy, should be maintained. The Qualified Medical Physicist should review these records at least annually.

The QC activities described in this section are broadly separated into three categories: acceptance testing, annual equipment performance evaluation and continuous QC testing.

QC of a hybrid scanner, such as PET/MRI, requires monitoring the performance of both modalities individually. PET and MRI QC are addressed in detail in other Technical Standards and publications. In this PET/MRI Technical Standard, the key elements of QC are outlined separately, with references as appropriate. In addition to subsystem-specific evaluations, some tests are designed to assess the integrated performance of PET and MRI as a hybrid system. These tests may not be well-addressed in each modality's references.

In addition to the following lists of performance tests, there may be additional vendor QC tests for a specific scanner.

IV. QUALITY CONTROL

A. Acceptance Testing

A Qualified Medical Physicist must conduct initial PET/MRI equipment performance evaluation upon installation of the equipment and after major repairs or upgrades. This evaluation should be more comprehensive than periodic evaluation and should be completed before clinical use. Baseline measurements should be documented for comparison with future performance evaluations, ensuring that the system meets clinical and research requirements.

Prior to acceptance testing, initial compliance with relevant regulatory requirements and special contractual terms must be met. Additionally, electrical safety and informatics connectivity (eg, DICOM transfer) must be verified by appropriate personnel. Initial site-specific radiation safety and MR safety program must be established and should be reviewed periodically for relevance, applicability, and continuous improvement, as specified in Section VI *Radiation Safety in Imaging* and Section VII *MR Safety Guidelines*. For example, MR-suitability of radiation safety equipment (eg, Geiger-Mueller meter) must be certified. Evaluation of system-specific MR safety information and appropriate means of hearing protection should be performed prior to performance evaluation. These requirements are in accordance with ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging Equipment [1].

Acceptance testing and/or commissioning must include tests performed during the annual performance evaluation (section IV.B) and, additionally, should include the following items:

PET subsystem:

- Energy resolution (for applicable systems)
- Timing resolution (for applicable systems)

MRI subsystem:

- Review of radiofrequency (RF) attenuation tests (e.g., radiofrequency shielding)
- Evaluation of magnetic fringe fields (e.g,, static magnetic field shielding)

Combined PET/MRI system:

- Compatibility of MRI components (e.g., coils) with PET subsystem (e.g., artifacts, attenuation correction accuracy)
- Processing monitor performance

IV. QUALITY CONTROL

B. Equipment Performance Evaluation

The performance of each PET/MRI system must be evaluated at least annually. In many cases, annual tests and acceptance tests overlap, but the focus of annual testing is to detect performance changes over time, as opposed to baseline performance established at acceptance.

Annual performance evaluations are required to assess the ongoing integrity of each PET/MRI system. These evaluations focus on identifying deviations from baseline performance and must be performed by a Qualified Medical Physicist. Evaluations include both mechanical and image quality assessments of the PET and MRI subsystems, as well as the hybrid integration features. Results should guide preventive maintenance and support compliance with accreditation requirements.

At a minimum, this evaluation should include the following items:

PET subsystem:

- Count rate performance (count rate versus activity), including corrections for count losses and random coincidences
- Sensitivity
- Image uniformity (full axial extent of scanner) and artifacts assessment
- Image spatial resolution
- Image contrast
- Accuracy of attenuation and scatter corrections, and standardized uptake value (SUV) or activity concentration

MRI subsystem:

- Magnetic field homogeneity
- Slice position accuracy and table positioning
- Slice thickness accuracy
- Geometric accuracy (gradient calibration)
- High-contrast spatial resolution
- Low-contrast resolution (detectability)
- Performance evaluation for radiofrequency coils used clinically
    - Visual inspection of physical coil
    - Transmitter gain/attenuator verification
    - Image artifact assessment
    - Image signal-to-noise ratio (SNR)
    - Image intensity uniformity (volume coils)
    - Percent signal ghosting (volume coils)
    - Year-to-year variations of each of the above parameters should be tracked

Combined PET/MRI system:

- PET and MRI 3D coregistration accuracy

Other performance evaluations:

- Acquisition workstation monitor performance
- Evaluation of technologist QC program and data

- Review of service log
- Safety (e.g., mechanical and electrical systems integrity inspection, assessment of MR safety and radiation safety programs)

IV. QUALITY CONTROL

C. Continuous Quality Control

A continuous QC program must be implemented for all PET/MRI systems with the assistance of a Qualified Medical Physicist. Periodic QC is performed to detect early signs of performance drift and ensure consistent system functionality. The Qualified Medical Physicist should determine the test frequency and tolerances, in conjunction with manufacturer specifications, unless defined by state or federal regulations. Automated diagnostic routines and phantom-based tests may be incorporated to support efficient QC practices.

At minimum, the QC program should include the following:

PET subsystem and equipment:

- Daily PET detector check
- Time-of-flight timing calibration (if applicable)
- Detector normalization calibration (quarterly, at minimum)
- Sensitivity calibration (quarterly, at minimum)
- SUV accuracy (quarterly, at minimum)
- PET image quality phantom (semiannual at minimum, quarterly recommended)
- Dose calibrator QC (with frequency as defined by state or federal regulations)
- Clock synchronization

MRI subsystem:

- Setup and table positioning accuracy
- Center frequency
- Transmitter gain or attenuation (RF calibration)
- Geometric accuracy (gradient calibration)
- High-contrast spatial resolution
- Low-contrast detectability or SNR
- Artifact evaluation
- Visual checklist

Combined PET/MRI:

- PET and MRI coregistration accuracy (after service repair)

Monitoring requirement after replacement or repair of a major component:

If a major component is replaced or repaired, a Qualified Medical Physicist must, in a timely manner, evaluate the need for performance testing of the PET/MRI scanner. The scope of the evaluation should be determined by the Qualified Medical Physicist based on the type of component that was replaced or repaired. Major repairs that must involve participation or oversight by the Qualified Medical Physicist include, but are not limited to, PET detector module replacement, deletion of scanner calibration files and gradient coil replacement. Software upgrades can affect scanner performance and MR safety, and therefore, the Qualified Medical Physicist should communicate with the manufacturer to determine the potential impact(s) and test accordingly.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Qualified Medical Physicist

A Qualified Medical Physicist must perform acceptance testing and equipment performance evaluation, and oversee continuous QC of PET/MRI systems as defined in section IV of this document. For the purposes of this

Technical Standard, the qualifications and duties of a Qualified Medical Physicist for the MRI subsystem can be replaced by those of a MR Scientist.

The qualifications and responsibilities of an MR Scientist are defined in ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance (MR) Imaging Equipment [1].

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields of 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. 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 Physicists in Medicine (CCPM), the American Board of Science in Nuclear Medicine (ABSNM), or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) [5].

The appropriate subfields of medical physics for this standard are Nuclear and Diagnostic Medical Physics. See the ACR policy on Physics for medical physics certifications categories that are also acceptable. (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022, Resolution 41f)

The Qualified Medical Physicist is responsible for the test protocols, test methods and acceptability criteria. The Qualified Medical Physicist may be assisted by properly trained individuals, such as Medical Physics Assistants, in obtaining data in accordance with applicable regulations and relevant guidance (e.g., AAPM medical physics practice guideline 7.a) [6]. Medical physics students, medical physics residents, and medical physicists-in-training may assist the Qualified Medical Physicist based on their training and at the discretion of the Qualified Medical Physicist [7]. These individuals must be properly trained and approved by the Qualified Medical Physicist such that they have knowledge about the techniques needed to perform tests, the functions and limitations of the equipment and test instruments, the reasons for the tests, and the importance of the test results. Additionally, these individuals must have the appropriate safety training (i.e., radioactive materials training and MR safety training). The assisting individual shall be under the supervision of the Qualified Medical Physicist during all testing procedures. The Qualified Medical Physicist is responsible for all surveys and must review, interpret and approve all data as well as provide a signed report with conclusions and recommendations [8].

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

B. Physician

For physician qualifications related to PET/MRI equipment, see the ACR–ACNM–SNMMI–SPR Practice Parameter for the Performance of Positron Emission Tomography Magnetic Resonance Imaging (PET/MRI).

Physician responsibilities when assuming the role of supervising physician of the QM team include:

1. Quality and Operational Oversight
   Working in collaboration with the Qualified Medical Physicist, lead MRI technologist and lead nuclear medicine technologist, the supervising physician oversees clinical and technical operations, including implementation of QA and CQI (continuous quality improvement) initiatives.

2. Policy and Procedure Manual
   The supervising physician must ensure the development, annual review and timely revision of a policy and procedure manual. This document must include guidelines for managing special populations (e.g., pregnant patients, pediatric cases, patients with anxiety or claustrophobia, individuals requiring sedation, large body habitus, prisoners, parolees). Oversight can be delegated to a specialized team, but the physician remains ultimately responsible.

3. Patient Protocol Manual

A separate patient protocol manual must be reviewed annually and updated as needed. A protocol review team should manage this process and ensure compliance with applicable regulations.

4. QA and Safety Documentation
   The supervising physician must work with the Qualified Medical Physicist or MR Scientist and lead technologist to develop a QA procedures manual accessible to all staff. The laboratory safety manual must also be reviewed annually in consultation with the radiation safety officer to ensure alignment with evolving safety risks.

5. Resource Allocation and Equipment Oversight
   The supervising physician must ensure sufficient staff time and resources for required QC, with well-defined processes for reporting and resolving equipment issues. These practices preserve diagnostic integrity and patient safety.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

C. Technologist

See the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [9] and the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [10].

A. Nuclear Medicine Technologist

The technologist preparing or administering diagnostic radiopharmaceuticals must meet all of the following criteria:

1. Successful completion of an accredited program in nuclear medicine technology. This program must include education in the basic and medical sciences as they apply to nuclear medicine technology and practical experience in performing nuclear medicine procedures. The technologist must satisfy all state and federal regulations that pertain to the *in vivo* and *in vitro* use of radiopharmaceuticals and performance of imaging examinations.

   OR

   Hold current registration with the American Registry of Radiologic Technologists (ARRT)(N) or equivalent body as recognized by the ACR, or certification by the Nuclear Medicine Technology Certification Board (NMTCB).

   AND

2. Licensure or other credential, if required by state regulations.

3. Documented regular participation in continuing education to maintain competence in the workplace.

4. Knowledge of radiation safety and protection; the compounding, preparation, and administration of radiopharmaceuticals; all aspects of performing examinations; operation of equipment; handling of medical and radioactive waste; patient safety; and applicable rules and regulations.

B. MRI Technologist

The technologist performing MRI should:

1. Be certified by the ARRT or the American Registry of MRI Technologists (ARMRIT) in MRI, or by the Canadian Association of Medical Radiation Technologists (CAMRT) as an MRI technologist (RTMR).

OR

2. Be certified by the ARRT in radiography, radiation therapy, or nuclear medicine, and have appropriate state licensure and have supervised clinical experience in MRI scanning.

   OR

3. Have an associate's degree in an allied health field or a bachelor's degree and certification in another clinical imaging field and have supervised clinical MRI scanning experience.

Any technologist practicing MRI scanning should be licensed in the jurisdiction in which they practices, if state licensure exists. To assure competence, all technologists must be evaluated by the supervising physician.

The MRI technologist should participate directly in assuring patient comfort and safety, preparing and positioning the patient for the MRI examination, and obtaining the MRI data in a manner suitable for interpretation by the physician. The technologist should also perform frequent QC testing in accordance with the MRI manufacturer's recommendations.

Additionally, all technologists working on the PET/MRI system should comply with radiation safety and MR safety training as described in sections VI and VII.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

D. Medical Physicist Assistant

A Medical Physicist Assistant is an individual who has the necessary didactic education and practical medical physics knowledge to work under the supervision and responsibility of a Qualified Medical Physicist [6, 11], such as technologists performing testing under the proper guidance of a Qualified Medical Physicist. As outlined in AAPM Medical Physics Practice Guideline 7.a, a Medical Physicist Assistant is an individual who is not a Qualified Medical Physicist but extends to a Qualified Medical Physicist through a formal chain of authority. The Medical Physicist Assistant is a valuable member of the QM team and QM program.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

E. Radiation Safety Officer

The Radiation Safety Officer must meet applicable requirements of the Nuclear Regulatory Commission (NRC) for training as specified in 10 CFR 35.50 [12] or equivalent state regulations.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

F. Information Technology (IT) Professional

IT professionals are essential to the implementation and continued operations of a PET/MRI system. The complexity of data to be transferred between the PET/MRI and PACS or display devices requires a robust and comprehensive data transfer QM program.

The Data Manager/IT Specialist oversees the configuration, connectivity and management of the PET/MRI software and any hardware interfaces. Management includes monitoring software logs, vendor upgrade announcements and field notices.

VI. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers**,** radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management

of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals in accordance with ALARA principles. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by applicable state, local, or other relevant regulatory agencies and accrediting bodies, as appropriate. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol, using body habitus or other customized method when such guidance is available.

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

An important consideration with PET/MRI systems is the inability to use regular radiation survey meters (Geiger-Mueller meters) in Zone IV in the event of radioactive contamination or spill, due to their incompatibility with large magnetic fields. MRI Safe or MRI Conditional radiation monitors should be used in such cases to ensure compliance with radiation safety limits and to optimize handling of radiopharmaceuticals.

VII. MR SAFETY GUIDELINES

Hybrid PET/MRI systems present unique safety challenges due to the combination of modalities that require distinct personnel qualifications, training and access protocols [13-15]. Governance can be complex given the integration of strong magnetic fields, RF energy and ionizing radiation. These factors necessitate clear communication and a well-defined delineation of responsibilities across teams.

PET/MRI facilities must establish and maintain a comprehensive MR safety program in accordance with the ACR Manual on MR Safety [16]. In the absence of a single physician who is qualified in both MRI and PET imaging, a commonly adopted and effective governance structure is a co-directorship model between an MRI physician and a second physician trained in nuclear medicine and authorized to handle radioactive materials (i.e., an authorized user). These co-directors should collaboratively develop policies and standard operating procedures (SOPs) to ensure compliance with contemporary MR and PET safety standards [16].

The MR Medical Director is responsible for overseeing the MR safety program for the PET/MRI facility, ensuring the safety of patients, staff, and all personnel who may enter or work in the MRI environment [16]. This includes maintaining records related to MRI subsystem quality control, safety and protection, as specified in the ACR Magnetic Resonance Imaging Quality Control Manual [17]. A Qualified Medical Physicist or MR Scientist must review these records at least annually. In conjunction with the MR system evaluation, the Qualified Medical Physicist or MR Scientist must ensure that MR safety information from the PET/MRI system operator's manual is readily available at the system console. MRI system-specific safety information, as required by IEC 60601-2-33 [18], should be clearly documented in the operator's manual. Guidance on the development and use of safety checklists is provided in AAPM Medical Physics Practice Guideline 4.b [19].

Practices concerning the administration of MRI contrast agents and recommendations regarding gadolinium-based contrast media (GBCM) usage, adverse reactions, nephrogenic systemic fibrosis, and retained or residual gadolinium should align with the recommendations of the ACR Manual on Contrast Media [20]. MRI contrast agents must not be administered to any patient without a valid order from a licensed physician or advanced practice provider [21].

In addition to standard MR safety considerations, PET imaging introduces further complexities within the MRI

environment [16]:

- Screening and Training:
  All patients and staff must undergo thorough MR safety screening to detect contraindications such as implanted devices, metallic foreign bodies or conditions affected by RF heating. Advanced metal detection technologies and AI-assisted questionnaires can improve screening accuracy. Personnel involved in PET procedures within Zones III and IV should complete at least Level 1 MR safety training, following institutional policies. All MR safety practices must be overseen by Level 2 MRI personnel.

- Magnetic Field and RF Safety:
  Strict magnetic field safety protocols must be enforced, including controlled access to the MRI scanner room and proper labeling of all ferromagnetic items. Specialized PET equipment (e.g., shielded syringes, phantoms) must be assessed for ferromagnetic properties prior to entering Zone IV.

- Emergency Preparedness:
  Facilities must implement emergency response protocols that address both PET-related incidents (e.g., radioactive spills) and MR-specific emergencies (e.g., magnet quench, projectile accidents, RF burns, entrapment, blunt force trauma, contrast reactions). If a radioactive spill occurs in Zone IV and an MRI Conditional survey meter is unavailable, a wipe test may be required to safely transfer the contaminated sample to Zone III for radiation assessment. Regular safety drills and staff education should be part of ongoing training. Emergency quench procedures and evacuation plans must be clearly documented and periodically reviewed.

VIII. RADIATION SHIELDING CONSIDERATIONS

Special care must be exercised regarding radiation shielding requirements for PET/MRI facility design. Appropriate shielding must be provided for patient injection and uptake rooms, PET/MRI examination suites, hot labs, and any other areas where PET radiopharmaceuticals are produced, prepared, used, disposed of or stored. Due to the high energy of annihilation radiation used in PET, the amount and type of shielding materials needed to protect adjacent areas typically differs from those used in X-ray or conventional nuclear medicine. A Qualified Medical Physicist should be consulted early in the facility design planning stages to determine shielding requirements and ensure structural design issues, created from using the larger amounts of shielding, can be assessed. The AAPM Task Group 108 report PET and PET/CT Shielding Requirements, in conjunction with the National Council on Radiation Protection Report 147, should be used as references in determining PET/MRI shielding requirements [22, 23].

Of particular concern for PET/MRI (versus PET or PET/CT) is the interaction of radiation shielding materials with the MRI subsystem and environment. Any materials incorporated as part of the MRI Zone IV room wall structures should undergo approval by the scanner vendor to ensure no adverse impact on MRI scanning performance or expected spatial containment of fringe fields such as the 5G or 9G magnetic field line. As MRI static field shielding within the Zone IV wall structures is commonly implemented using ferrous steel (e.g., M36 silicon steel or C1006 plate steel), potential ferrous elements of permanent embedded radiation shielding materials (e.g., sintered tungsten often contains iron or nickel) are not generally a safety concern for MRI. However, if radiation shielding materials are to be used within the MRI Zone IV environment, such as for portable syringe shielding, these materials should be certified or tested as MRI Safe or MRI Conditional. If materials used within Zone IV are only MRI Conditional, protocols should be established to ensure that these elements are used in a manner corresponding to the MRI conditions associated with no known risk usage.

IX. 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 ACR Quality Control and Improvement, Safety, Infection Control, and Patient Education Concerns on the ACR Policy Finder; 2018 (Res. 33-v).

ACKNOWLEDGEMENTS

This technical standard was developed according to the process described under the heading *Process for*

Developing ACR Practice Parameters and Technical Standards on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards) by the Committee on Practice Parameters and Technical Standards – Medical Physics of the ACR Commission on Medical Physics, in collaboration with AAPM.

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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.

Development Chronology for this Technical Standard
2026 (CSC/BOC)