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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.

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ACR TECHNICAL STANDARD FOR MEDICAL NUCLEAR PHYSICS PERFORMANCE MONITORING OF PET-CT IMAGING EQUIPMENT

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 on 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

Positron emission tomography – computed tomography (PET-CT) systems are truly a new imaging tool. Even though they can be operated to acquire either CT images or PET images, they are mainly operated to acquire both, combining two medical imaging technologies: X-ray CT for anatomical imaging, and attenuation correction and PET for functional imaging. This brings the advantages and also the complexities of both systems while providing anatomical and functional aspects through fusion images. Therefore, all PET-CT equipment shall be tested on installation and monitored at least annually by a Qualified Medical Physicist to ensure proper functioning within the manufacturer's specifications and accepted performance standards. 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 variations of equipment performance to be monitored, adherence to this standard will maximize image quality and help to ensure the accuracy of quantitative results in clinical procedures. Key points to consider are performance characteristics, patient radiation dose, qualifications of personnel, and follow-up procedures.

II. GOAL

The primary goal of PET-CT imaging is to produce highly accurate fusion images with proper registration of both CT and PET images on the same platform. An additional goal is to produce images with the lowest reasonable radiation dose consistent with the clinical use of the equipment and the information requirements of the examination. The goal of this document is to establish performance standards.

III. QUALIFICATIONS AND RESPONSIBILITIES OF A QUALIFIED MEDICAL PHYSICIST

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 of medical physics for this standard is Radiological Physics.

or

Medical Nuclear Physics with continuing medical physics education in CT physics.

or

Diagnostic Radiological Physics with continuing medical physics education in PET imaging physics.

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

Certification in Nuclear Medicine Physics and Instrumentation by the American Board of Science in Nuclear Medicine (ABSNM) is also acceptable with continuing medical physics education in CT physics.

Regardless of certification, 40 hours of practical clinical experience in PET imaging and CT imaging is required.

The medical physicist must be familiar with the principles of imaging physics and radiation protection; the guidelines of the National Council on Radiation Protection and Measurements (NCRP); laws and regulations pertaining to the use of the equipment being tested; the function, clinical uses, and performance specifications of the imaging equipment; and calibration

processes and limitations of the instruments and the techniques used for testing performance.

The medical physicist may be assisted by properly trained individuals in obtaining data. These individuals must be approved by the medical physicist in the techniques of performing tests, the function and limitations of the imaging equipment and test instruments, the reasons for the tests, and the importance of the test results. The medical physicist is responsible for and must review, interpret, and approve all data, and must provide a signed report of the conclusions.

IV. PERFORMANCE CHARACTERISTICS TO BE MONITORED

A. Characteristics to be Monitored for PET

The medical physicist must design a quality assurance (QA) program that includes regular testing procedures to insure proper operation on a daily basis. Quarterly testing with a 3D phantom for uniformity, resolution, and contrast is recommended. The PET-CT program should be reviewed at least semiannually.

The procedures should include as a minimum, those recommended by the manufacturer. Specific attention should be given to daily quality control (QC) for attenuation blanks, detector operation, and any necessary normalization scans.

The following characteristics shall be evaluated for the equipment to which they apply on at least an annual basis:

1. Spatial resolution
2. Count rate performance (count rate versus activity), including count loss correction. Specific measurements of the following are recommended.
 - a. Total coincidences
 - b. Random coincidences
 - c. Scatter coincidences
 - d. Net true coincidences
 - e. Noise equivalent count rate
3. Sensitivity (cps/MBq/ml) in 2-dimensional (2D) and 3-dimensional (3D) modes as applicable
4. Image quality, accuracy of attenuation and scatter corrections

B. Characteristics to be Monitored for CT

Performance of each CT unit must be monitored at least annually. This evaluation should include, but not be limited to:

1. Alignment light accuracy
2. Alignment of table to gantry

3. Multiple-row detector assembly and available scan modes
4. Slice localization from scanned projection radiograph (localization image)
5. Table increment accuracy
6. Slice thickness
7. Image quality
 - a. High-contrast (spatial) resolution
 - b. Low-contrast sensitivity and resolution
 - c. Image uniformity
 - d. Noise
 - e. Artifact evaluation
8. CT number accuracy and linearity
9. Display devices.
 - a. Image display monitor(s)
 - b. Hardcopy display unit(s), if available
10. Dosimetry (if the CT scanner is used for other than low dose attenuation)
 - a. CT dose index (CTDI)
 - b. Patient radiation dose for representative examinations
 - c. Review of pediatric dose reduction protocols
 - d. Monitoring of pediatric specific (typically weight-based) doses
11. Safety evaluation
 - a. Visual inspection
 - b. Work load assessment
 - c. Scatter and stray radiation measurements (if work load and other related parameters have changed since acceptance testing)
 - d. Audible and visual signals
 - e. Posting requirements
12. Other tests as required by state and/or local regulations

C. Specific Tests for PET-CT

The performance of either the PET or the CT system can affect the overall performance of dual-modality imaging. Each system should be tested individually, as stated previously, and together to examine coregistration. For this purpose, specially designed phantoms shall be scanned on both the PET and CT systems. Accuracy of coregistration shall be determined by established procedure.

D. Patient Radiation Dose: CT Only

Patient radiation dose for CT equipment shall be evaluated at least annually. Tables of adult and pediatric (if performed) patient radiation absorbed dose for representative examinations (e.g., head, thorax, abdomen, pelvis, and whole-body) shall be prepared and supplied to the facility. These results shall be compared with appropriate guidelines or recommendations when they are available.

E. Organ Doses from Radiopharmaceuticals: PET Only

A table of organ doses shall be prepared for all procedures that involve administration of radiopharmaceuticals to patients. The table shall specify the dosage schedule used at the facility. All organs that receive significant doses shall be included. Separate values for patient size and gender shall be tabulated where applicable. The table shall be reviewed at least annually and updated when any of the following occur: the addition of new procedures and/or radiopharmaceuticals, the change in dosage schedules, the change in route of administration, and the availability of more accurate dosimetry data.

V. ACCEPTANCE TESTING

Initial performance testing of imaging equipment shall be performed upon installation and should be completed before clinical use. This testing should be more comprehensive than periodic performance testing and shall be consistent with current acceptance testing practices.

VI. FOLLOW-UP PROCEDURES AND WRITTEN SURVEY REPORT

The medical physicist or other qualified individual shall report the findings to the physician(s), to the responsible professional(s) in charge of obtaining or providing necessary service to the equipment, and, in the case of the consulting physicist(s), to the representative of the hiring party. If appropriate, the medical physicist shall initiate the required service. Action should be taken immediately by direct verbal communication if there is imminent danger to patients or staff using the equipment due to unsafe conditions. Written survey reports shall be provided in a timely manner consistent with the importance of any adverse findings.

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, radiologic technologists, and all supervising physicians have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This concept is known as “as low as reasonably achievable (ALARA).”

Facilities, in consultation with the medical physicist, should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active; if not, manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic

image quality. Patient radiation doses should be periodically measured by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006)

VIII. RADIATION SHIELDING CONSIDERATIONS

Special care must be exercised regarding radiation shielding requirements for PET-CT facility design. Appropriate shielding must be provided for patient injection/uptake rooms, PET-CT imaging suites, and any other areas where PET radiopharmaceuticals are prepared, used, or stored. Due to the high energy of annihilation radiation used in PET, the amount of shielding materials needed to protect adjacent areas is typically much larger than that for conventional CT scanners or other diagnostic imaging modalities. A medical physicist should be consulted early in facility design planning stages so that shielding requirements can be determined and structural design issues, created from using the larger amounts of shielding can be assessed. The American Association of Physicists in Medicine 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 a reference in determining PET-CT shielding requirements.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

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 Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

A continuous QC program shall be established for the PET-CT systems with the assistance of a medical physicist consistent with the recommendations of the [ACR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#). Additional tests to evaluate quantitative parameters (e.g., standardized uptake value) should be performed. The medical physicist should determine the frequency of each test and who should perform each test based on the facility and PET-CT usage. An on-site technologist shall be identified to be responsible for conducting routine QC.

The results of the QC program shall be monitored annually by the medical physicist. If measured values of QC parameters fall outside the control limits, the physicist should initiate appropriate investigative or corrective

actions. A medical physicist should be available to assist in prescribing corrective actions for unresolved problems.

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