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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.

2009 (Resolution 6)\*

## **ACR TECHNICAL STANDARD FOR MEDICAL PHYSICS PERFORMANCE MONITORING OF SPECT-CT IMAGING EQUIPMENT**

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### **PREAMBLE**

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

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations 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**

Combined single photon emission computed tomography – computed tomography (SPECT-CT) systems have been introduced in recent years [1]. These systems are primarily designed to acquire sequential SPECT and CT datasets. Some of these systems are capable of being used for CT imaging alone, while others have CT capabilities that are nondiagnostic. In either case, a SPECT-CT system combines two medical imaging technologies, X-ray CT for anatomical imaging and attenuation correction and SPECT for functional imaging. These systems have both the advantages and the complexities of each subsystem. The mechanically fused images obtained from a SPECT-CT system provide anatomical and functional information that can only be obtained otherwise by software fusion of independently acquired images.

All SPECT-CT imaging equipment shall be tested on installation and monitored at least annually by a 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 to be monitored, estimated patient radiation dose, qualifications of personnel, and follow-up procedures.

## II. GOAL

The primary goal of SPECT-CT imaging is to produce highly accurate fusion images with proper registration of both CT and SPECT 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 [2]. The goal of this document is to establish performance standards for the imaging instruments [3].

## III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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 education in CT physics.

or

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

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

The continuing education should include at least 15 hours in medical nuclear physics in the prior 36 month period; at least half of these hours should be category 1.

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

Regardless of certification, 40 hours of practical clinical experience in SPECT 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 techniques used for testing performance.

The medical physicist is responsible for:

1. The design of the overall program of performance monitoring (including selection of specific methods for acceptance testing and quality control testing).
2. Documentation of program goals, policies, and procedures.
3. Documentation of the results of all performance measurements.
4. Review and approval of all measurements performed by other designated personnel.

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 as well as provide a signed report of the conclusions.

## IV. PERFORMANCE CHARACTERISTICS TO BE MONITORED

### A. Performance Evaluation

1. Characteristics to be monitored for SPECT

The performance of the SPECT subsystem in each unit must be monitored at least annually by a medical physicist. This evaluation should be based on the [ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of Gamma Cameras](#) [4] and may include, but not be limited to:

- a. Planar image quality.
  - i. System uniformity and intrinsic uniformity, if possible.
  - ii. Spatial resolution (intrinsic or system).
  - iii. Spatial linearity.
  - iv. Energy resolution.
  - v. Sensitivity.

- vi. Multiple window spatial registration.
  - vii. Count rate capability.
  - viii. Collimator integrity.
  - b. Tomographic image quality.
    - i. Uniformity and noise.
    - ii. Spatial resolution.
    - iii. Contrast.
  - c. Safety features and interlocks.
  - d. Other tests as described in standards of the National Electrical Manufacturers Association (NEMA) [5,6].
2. Characteristics to be monitored for CT

The performance of the CT subsystem in each unit must be monitored at least annually by a medical physicist. This evaluation should be based on the [ACR Technical Standard for Medical Physics Performance Monitoring of Computed Tomography \(CT\) Equipment](#) [7] and may include, but not be limited to:

- a. Alignment light accuracy.
- b. Alignment of table to gantry.
- c. Multiple-row detector assembly and available scan modes.
- d. Slice localization from scanned projection radiograph (localization image).
- e. Table increment accuracy.
- f. Slice thickness.
- g. Image quality.
  - i. High-contrast (spatial) resolution.
  - ii. Low-contrast sensitivity and resolution.
  - iii. Image uniformity.
  - iv. Noise.
  - v. Artifact evaluation.
- h. CT number accuracy and linearity.
- i. Display devices.
  - i. Image display monitor(s).
  - ii. Hardcopy display unit(s), if available.
- j. Dosimetry (if the CT scanner is used for other than low dose attenuation).
  - i. CT dose index (CTDI).
  - ii. Patient radiation dose for representative examinations.
  - iii. Review of pediatric dose reduction protocols.
  - iv. Monitoring of pediatric specific (typically weight-based) doses.
- k. Safety evaluation.
  - i. Visual inspection.
  - ii. Work load assessment.
  - iii. Scatter and stray radiation measurements (if work load and other related parameters have changed since acceptance testing).
  - iv. Audible and visual signals.
  - v. Posting requirements.

- l. Tests required by state and/or local regulations.
  - m. Other tests as described in AAPM Report 39 [8] and other publications [9,10].
3. Specific tests for SPECT-CT

The performance of the combined system must be monitored at least annually by a medical physicist. This evaluation should include, but not be limited to:

- a. Accuracy of coregistration of SPECT and CT images. For this purpose, specially designed phantoms shall be scanned on both SPECT and CT subsystems. Accuracy of coregistration shall be determined by the manufacturer's established procedure at installation and after any major changes that might affect coregistration.
  - b. Accuracy of CT based attenuation correction.
4. Patient radiation dose estimates: CT

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 [11]. These results shall be compared with appropriate guidelines or recommendations when they are available. See the [ACR Practice Guideline for Diagnostic Reference Levels in Medical X-Ray Imaging](#).

5. Organ dose estimates from radiopharmaceuticals : SPECT

The medical physicist shall prepare a table of organ dose estimates for all procedures that involve administration of radiopharmaceuticals to patients [12]. The table shall specify the radiopharmaceutical 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: 1) addition of new procedures and/or pharmaceuticals, 2) change in radiopharmaceutical dosage schedules, 3) change in route of administration, and 4) availability of more accurate dosimetry data.

## B. Quality Control Program

A continuous quality control (QC) program shall be established with the assistance of a medical physicist and implemented for all SPECT-CT units. Appropriately trained on-site technologists shall be identified to be responsible for conducting routine QC. The program should be consistent with the recommendations of the [ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#) [13] and the [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography \(CT\) Equipment](#) [7]. In addition it is recommended that the QC program includes:

1. Quarterly testing of the SPECT subsystem with a 3D phantom for uniformity, resolution, and contrast.
2. Quarterly checks of the alignment between the CT and SPECT subsystems. Such a gantry alignment check should determine any offset between the CT and SPECT subsystems to be incorporated into the fused image display to ensure accurate image alignment [2].
3. Testing recommended by the manufacturer.

The medical physicist should determine the frequency of each test and who should perform each test based on the facility and SPECT-CT usage.

The medical physicist should periodically monitor the results of the QC program. If measured values of QC parameters fall outside the control limits, the physicist should initiate appropriate investigative or corrective actions. The medical physicist should be available to assist in prescribing corrective actions for unresolved problems.

In addition, regular preventive maintenance should be performed and documented by a qualified equipment service engineer following the recommendations of the equipment vendor.

## C. Acceptance Testing

Initial performance testing of imaging equipment shall be performed by the medical physicist 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.

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

The medical physicist shall provide a written report of the findings to the physician(s), to the responsible professional(s) in charge of obtaining or providing 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 should initiate any servicing required. 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. As appropriate, the medical physicist should confirm that the unit is performing in a safe and acceptable fashion as soon as possible after the required service is performed.

## V. RADIATION SAFETY IN IMAGING

Radiologists, medical physicist, imaging 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 radiation safety officer, should have in place and should adhere to policies and procedures for the safe handling and administration of radiopharmaceuticals, in accordance with ALARA, and must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) [14], state, and/or other regulatory agencies. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol. CT protocols should 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. Periodically, radiation exposures should be measured and patient radiation doses estimated by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006 – revised in 2009, Resolution 11)

## VI. RADIATION SHIELDING CONSIDERATIONS

Attention must be given to radiation shielding requirements for SPECT-CT facility design. Appropriate shielding must be provided for SPECT-CT imaging suites and for any other areas where SPECT radiopharmaceuticals are prepared, used, or stored. A medical physicist should be consulted early in facility design planning stages so that shielding requirements can be determined. The NCRP Report #147 [15] should be used as a reference in determining SPECT-CT shielding requirements.

## ACKNOWLEDGEMENTS

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

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

Development Chronology for this Guideline  
2009 (Resolution 6)