NOT FOR PUBLICATION, QUOTATION, OR CITATION

ACR–AAPM TECHNICAL STANDARD FOR MEDICAL NUCLEAR PHYSICS PERFORMANCE MONITORING OF GAMMA CAMERAS

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 of 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

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

All nuclear medicine imaging equipment ~~shall~~ **must** be tested upon installation and monitored at least annually by a Qualified Medical Physicist ~~or other qualified individual~~ to ensure that it is functioning within manufacturer 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 numerical 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.

The goal is to produce the highest quality diagnostic image consistent with the clinical use of the equipment and the information requirement of the examination and to establish performance standards for the imaging instruments.

II. QUALIFICATIONS AND RESPONSIBILITIES OF A QUALIFIED MEDICAL PHYSICIST

A Qualified Medical Physicist is an individual who is competent to practice independently in 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. 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, or the American Board of Medical Physics (ABMP).

The appropriate subfield of medical physics for this standard is Nuclear Medical Physics. (Previous medical physics certification categories including radiological physics, therapeutic radiological physics, medical

nuclear physics, diagnostic radiological physics and diagnostic imaging physics are also acceptable.)

A Qualified Medical Physicist should meet the ACR Practice Guideline for Continuing Medical Education (CME). (ACR Resolution 17, adopted in 1996 – revised 2012, Resolution 42)

Certification in Nuclear Medicine Physics and Instrumentation by the American Board of Science in Nuclear Medicine (ABSNM) is also acceptable.

~~In addition 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~~

The Qualified Medical Physicist must be familiar with the principles of radiation protection; the guidelines of the National Council on Radiation Protection and Measurements (NCRP); laws and regulations governing 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 Qualified Medical Physicist may be assisted by properly trained individuals in obtaining data for performance monitoring. These individuals must be approved by the Qualified 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 Qualified Medical Physicist is responsible for, and must review, interpret, and approve all data as well as provide a signed report of the conclusions.

III. PERFORMANCE CHARACTERISTICS TO BE MONITORED

A. **Performance Evaluation** ~~Characteristics to be Monitored Annually~~

The following characteristics ~~shall~~ **should** be evaluated **at least annually [1-11].** ~~for the equipment to which they apply on at least an annual basis~~

1. **Intrinsic uniformity**
2. **System uniformity with all commonly used collimators**
3. **Intrinsic or system spatial resolution/linearity**
4. **System sensitivity**
    a. **Count rate per unit activity**
    b. **Interdetector variability**
5. **Energy resolution (if possible)**
6. **Count rate performance**
7. **Formatter/video display**
    a. **Uniformity**

b. Spatial resolution

8. Overall system performance for SPECT

a. Uniformity

b. Contrast

c. Spatial resolution

9. System interlocks

~~Planar image quality~~

~~a. System uniformity and intrinsic uniformity, if possible~~

~~b. Spatial resolution (intrinsic or system)~~

~~c. Spatial linearity~~

~~d. Energy resolution~~

~~e. Sensitivity~~

~~f. Multiple window spatial registration~~

~~g. Count rate capability~~

~~h. Collimator integrity~~

~~2. Tomographic image quality~~

~~a. Uniformity and noise~~

~~b. Spatial resolution~~

~~c. Contrast~~

~~3. Safety features and interlocks~~

B. Quality Control Program

A continuous quality control (QC) program must be established for the nuclear medicine imaging equipment with the assistance of a Qualified Medical Physicist as outlined in the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals [12,13]. An on-site technologist should be identified to be responsible for conducting routine QC.

The results of the QC program must be monitored annually by the Qualified Medical Physicist. If measured values of QC parameters fall outside the control limits, the physicist should initiate appropriate investigative or corrective actions. A Qualified Medical Physicist should be available to assist in prescribing corrective actions for unresolved problems.

C. Acceptance Testing

Initial performance testing of imaging equipment must be performed upon installation and should be completed before clinical use. This testing should be more comprehensive than periodic performance testing and should be consistent with current acceptance testing practices. Electrical safety of the equipment must also be tested by appropriate personnel prior to its initial clinical use.

D. Written Survey Reports and Follow-Up Procedures

The Qualified Medical Physicist must 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 Qualified Medical Physicist(s), to the representative of the hiring party. If appropriate, the Qualified Medical Physicist should 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 must be provided in a timely manner consistent with the importance of any adverse findings. The Qualified 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.

~~B. Estimates of Organ Dose from Radiopharmaceuticals~~

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

~~**IV. 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~~

~~**V. FOLLOW-UP PROCEDURES AND WRITTEN SURVEY REPORT**~~

~~The medical physicist 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, and, if appropriate, 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. 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~~

IV. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, 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] and by state ~~and/~~or other regulatory agencies. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol.

A table of organ dose estimates should be prepared for all procedures that involve administration of radiopharmaceuticals to patients. The table should specify the radiopharmaceutical dosage schedule used at the facility. All organs that receive significant doses should be included. Separate values for standard patients of different sizes or ages should be tabulated where applicable. The table should be reviewed at least annually and updated when any of the following occur: 1) the addition of new procedures and/or radiopharmaceuticals, 2) a change in radiopharmaceutical dosage schedules, 3) a change in the route of administration, and 4) the availability of more accurate dosimetry data [13,15-18]. For facilities performing pediatric imaging, the radiopharmaceutical dosage should be adjusted to lower the dose to the patient. It is recommended that the dosages closely follow the activities as outlined in the North American Consensus Guidelines for Administered Radiopharmaceutical Activities in Children and Adolescents [19].

~~VII. 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 *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR web page (http://www.acr.org/guidelines)~~

~~A continuous quality control (QC) program shall be established for the nuclear medicine imaging equipment with the assistance of a medical physicist as outlined in the ACR-SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals. 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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Collaborative Committee – members represent their societies in the initial and final revision of this guideline

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REFERENCES

1. **Bolster A. *Quality Assurance in Gamma Camera Systems*: Institute of Physics and Engineering in Medicine; 2003. Report 86.**
2. Forstrom LA, Dunn WL, O'Connor MK, Decklever TD, Hardyman TJ, Howarth DM. Technical pitfalls in image acquisition, processing, and display. *Semin Nucl Med* 1996;26:278-294.
3. **Garcia EV, Faber TL. New trends in camera and software technology in nuclear cardiology. *Cardiol Clin* 2009;27:227-236, Table of Contents.**
4. Graham LS, Fahey FH, Madsen MT, van Aswegen A, Yester MV. Quantitation of SPECT performance: Report of Task Group 4, Nuclear Medicine Committee. *Med Phys* 1995;22:401-409.
5. Henkin R ed. *Nuclear Principles and Practices.* Vol I and II. St. Louis, Mo: Mosby-Yearbook; 1996.
6. Hines H, Kayayan R, Colsher J, et al. National Electrical Manufacturers Association recommendations for implementing SPECT instrumentation quality control. *J Nucl Med* 2000;41:383-389.

7. O'Connor MK. Instrument- and computer-related problems and artifacts in nuclear medicine. *Semin Nucl Med* 1996;26:256-277.
8. International Atomic Energy Agency. IAEA Quality Control Atlas for Scintillation Camera Systems. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1141_web.pdf. Accessed January 30, 2012.
9. Sandler M ed. *Diagnostic Nuclear Medicine*. 4th ed. Baltimore, Md: Lippincott, Williams and Wilkins; 2003.
10. ***Performance Measurements of Gamma Cameras.*** **District of Columbia, DC: National Electrical Manufacturers Association; 2007. Standards Publication NU 1-2007.**
11. ***Quality Assurance for Radioactivity Measurement in Nuclear Medicine.*** **Vienna, Austria: International Atomic Energy Agency; 2006. Technical Reports Series No. 454.**
12. **ACR-SNM technical standard for diagnostic procedures using radiopharmaceuticals. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/nuc_med/radiopharmaceuticals.aspx. Accessed January 24, 2012.**
13. **Society of Nuclear Medicine procedure guideline for general imaging 6.0. *The Society of Nuclear Medicine Procedure Guidelines Manual*. Reston, Va: The Society of Nuclear Medicine; 2010.**
14. ***Consolidated Guidance About Medical Use Licenses.*** **District of Columbia, DC: Nuclear Regulatory Commission. Final Report NUREG-1556, Volume 9; Rev 2, 2008.**
15. ***Medical Internal Radiation Dose (MIRD) Reports*****. Reston, Va: Society of Nuclear Medicine.**
16. *Radiation Dose Estimated for Radiopharmaceuticals*. District of Columbia, DC: Nuclear Regulatory Commission. NUREG/CR 6345; 1996.
17. ICRP. Radiation Dose to Patients from Radiopharmaceuticals (Addendum to ICRP Publication 53). ICRP Publication 80. *Ann. ICRP* 1998; 28 (3).
18. Oak Ridge Institute for Science and Education. Dose Estimates and Other Compendia. http://orise.orau.gov/reacts/resources/dose-estimates.aspx. Accessed April 19, 2012.
19. **Gelfand MJ, Parisi MT, Treves ST. Pediatric radiopharmaceutical administered doses: 2010 North American consensus guidelines. *J Nucl Med* 2011;52:318-322.**

~~**Suggested Reading** (Additional articles that are not cited in the document but that the committee recommends for further reading on this topic)~~

~~1. ACR technical standard for diagnostic procedures using radiopharmaceuticals. In: *Practice Guidelines and Technical Standards*. Reston, Va: American College of Radiology; 2006;997-1003.~~
~~2. *Computer-Aided Scintillation Camera Acceptance Testing*. New York, NY: American Institute of Physics; AAPM Report 9; 1981.~~
~~3. *Conslidated Guidance About Medical Use Licenses*. District of Columbia, DC: Nuclear Regulatory Commission; Final Report NUREG-1556, Volume 9; 2002.~~

6. Hannon J. *Quality Control of Gamma Cameras and Associated Computer Systems*. York, England: The Institute of Physical Sciences in Medicine; Report 66; 1992.
10. *Medical Internal Radiation Dose (MIRD) Reports*. Reston, Va: Society of Nuclear Medicine.
12. Parker JA, Yester MV, Graham LS, et al. Society of Nuclear Medicine procedure guideline for general imaging. In: *The Society of Nuclear Medicine Procedure Guidelines Manual*. Reston, Va: 1997:55-62.
13. *Performance Measurements of Scintillation Cameras*. District of Columbia, DC: National Electrical Manufacturers Association; Standards Publication NU 1-2001; 2001.
14. *Quality Control of Nuclear Medicine Instruments*. Vienna, Austria: International Atomic Energy Agency; IAEA-TECDOC-602; 1991.
16. *Rotating Scintillation Camera SPECT Acceptance Testing and Quality Control*. New York, NY: American Institute of Physics, AAPM Report 22; 1987.
18. Webster JG. *Encyclopedia of Medical Devices and Instrumentation*. Vols. 1-4. Wiley and Sons; 1988.
19. Wegst AV, Ashare A, Correia JA, et al. *Scintillation Camera Acceptance Testing and Performance Evaluation*. New York, NY: American Institute of Physics; AAPM Report 6; 1980.

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*Guidelines and standards are published annually with an effective date of October 1in 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.

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