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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.

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ACR–AAPM TECHNICAL STANDARD FOR DIAGNOSTIC MEDICAL PHYSICS PERFORMANCE MONITORING OF COMPUTED TOMOGRAPHY (CT) EQUIPMENT

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care¹. 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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document 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 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 sole purpose of this document is to assist practitioners in achieving this objective.

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

I. INTRODUCTION

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

The performance of all computed tomography (CT) equipment, whether it is part of a hybrid system (eg, positron emission tomography [PET/CT] or single-photon emission computed tomography [SPECT/CT]) or is a stand-alone system, must be evaluated upon installation to verify that it complies with manufacturer specifications and federal and local regulations and must be monitored periodically, the frequency depending on the complexity of the equipment.

Monitoring should be done at least annually or more often if required by state or local regulatory agencies, by a Qualified Medical Physicist to ensure that the equipment is functioning properly and that patients are not exposed to unnecessary radiation dose. Additional or more frequent monitoring may be necessary after repair or service (see [section III.B.2](#)) that might change the performance of the equipment, the image quality, or the radiation exposure to patients or personnel.

Although it is not possible to consider all possible variations of equipment performance to be monitored, adherence to this technical standard will assist in optimizing image quality and patient radiation dose [1-5]. Key points to consider are performance characteristics to be monitored, patient radiation dose, qualifications of personnel, and follow-up procedures.

The goals are to produce optimal-quality diagnostic images at an appropriate dose consistent with the clinical use of the equipment and the information requirement of the examination and to establish performance standards.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A Qualified Medical Physicist must carry out acceptance testing and monitoring of CT equipment.

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 in 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).

A Qualified Medical Physicist should meet the [ACR Practice Parameter for Continuing Medical Education \(CME\)](#). (ACR Resolution 17, adopted in 1996 – revised in 2012, Resolution 42) [6]

The appropriate subfield of medical physics for this technical standard is Diagnostic Medical Physics (including medical physics, certification categories of Radiological Physics, Diagnostic Radiological Physics, or Diagnostic Imaging Physics).

A Qualified Medical Physicist must be responsible for acceptance testing, routine performance evaluation, and providing support and consultation regarding the optimization of dose and image quality on the equipment. Understanding the relationship between image quality and patient radiation dose is essential for proper medical physics support.

The Qualified Medical Physicist must be familiar with:

1. Principles of imaging physics and of radiation protection.
2. The guidelines and recommendations of widely recognized authoritative bodies (such as the AAPM, and the National Council on Radiation Protection and Measurements [NCRP]).

3. Laws and regulations pertaining to the performance of the equipment being tested.
4. The function, clinical uses, and performance specifications of the imaging equipment.
5. Calibration processes and limitations of the instruments used for testing performance.

The Qualified Medical Physicist is responsible for the test protocols, the test methods and the acceptability criteria. The Qualified Medical Physicist may be assisted by properly trained individuals in obtaining data in accordance with applicable regulations. These individuals must be properly trained and approved by the Qualified Medical Physicist in the techniques of performing tests, the function and limitations of the imaging equipment and test instruments, the reason for the tests, and the importance of the test results. The assisting individual must be under the direct supervision² of the Qualified Medical Physicist during initial and annual surveys. 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 [7].

III. PERFORMANCE CHARACTERISTICS TO BE MONITORED

The monitoring of performance characteristics of CT equipment [1,5,8,9] must be evaluated as described below and in accordance with federal, state, or local regulations.

A. Acceptance Testing

Prior to initial physics testing, electrical safety and digital image communication must be verified by appropriate personnel.

Initial performance testing of imaging equipment must be performed by a Qualified Medical Physicist and should be completed before clinical use.

Acceptance tests must include:

1. Compliance with local regulatory requirements
2. Compliance with special contractual terms
3. Compliance with manufacturer's specifications
4. Evaluation of radiation shielding
5. Tests performed during the annual performance evaluation

B. Performance Evaluation

1. Equipment performance and patient dosimetry must be evaluated for each CT system at least annually. This evaluation, at a minimum, must include the following as applicable to the design of the CT scanner:
 - a. Alignment light accuracy
 - b. Image localization from scanned projection radiograph (localization image)
 - c. Table travel accuracy
 - d. Radiation beam width (collimation)
 - e. Image quality
 - i. High-contrast (spatial) resolution
 - ii. Low-contrast sensitivity and resolution
 - iii. Image uniformity
 - iv. Noise
 - v. Artifact evaluation
 - f. CT number accuracy
 - g. Acquisition workstation display

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

- h. Radiation output or dosimetry [8,10]
 - i. Measurement of radiation output of CT scanner (CT dose index [CTDI_{vol}] or other metric accepted by a nationally recognized organization)
 - ii. Measurement of doses for verification of scanner performance and to allow for calculation of dosimetric quantities relevant to patient examination estimates
 - iii. Comparison of calculated values to scanner-reported values. These comparisons should include both 16-cm and 32-cm dosimetry phantoms, as appropriate for the CT system and for use with the indicated protocols.
- i. Limited protocol review
 - i. The Qualified Medical Physicist must review a selection of the most commonly used protocols. These should include head and abdomen protocols for adult and pediatric patients as applicable to the facility's practice. In addition, facility protocols for very high-dose procedures (eg, brain perfusion) should be reviewed [11-13].
 - ii. The key elements associated with image quality and patient dose should be reviewed. These should include, but are not limited to [2,14-16].
 - kVp
 - mA
 - Rotation time
 - Detector configuration
 - Pitch
 - Reconstructed image thickness
 - Appropriate use of automated settings, such as tube current modulation, kVp selection, and image reconstruction parameters
 - Accuracy of indicated CTDI_{vol}
 - When possible, CTDI_{vol} should be compared to established reference values
- j. Safety evaluation
- k. Visual inspection
 - i. Workload assessment
 - ii. Scatter and stray radiation measurements (if workload and other related parameters have changed since acceptance testing)
 - iii. Audible/visual signals
 - iv. Posting requirements
- l. Other tests as required by state or local regulations

2. Monitoring required after replacement or repair of a major component

If a major component is replaced or repaired, a Qualified Medical Physicist should, in a timely manner, evaluate the need for performance testing of the CT 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 should involve participation or oversight by the Qualified Medical Physicist include X-ray tube replacement, high voltage generator replacement, detector assembly replacement, mA/kV modulation installation, and significant software upgrade [17].

C. Quality Control Program

A continuous quality control (QC) program must be established for all CT systems with the assistance of a Qualified Medical Physicist. The Qualified Medical Physicist should determine tolerances in conjunction with manufacturer specifications, the frequency of each test, and who should perform each test based on the facility and CT usage. An on-site radiologic technologist should be identified to be responsible for conducting routine QC.

The QC program should minimally include the following:

1. Water CT number accuracy

2. Noise (CT number standard deviation)
3. Artifact evaluation
4. Display devices
 - a. Acquisition work station
 - b. Hard-copy display unit(s), if used for patient images
5. Visual checklist

The results of the QC program must be monitored at least annually by the Qualified Medical Physicist. If measured values of QC parameters fall outside the established tolerances, the QC technologist should consult with the Qualified Medical Physicist. The Qualified Medical Physicist should recommend or, when appropriate, initiate investigative or corrective actions. A Qualified Medical Physicist should be available to assist in prescribing corrective actions for unresolved problems.

D. Written Survey Reports and Follow-up Procedures

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

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

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

IV. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, registered radiologist assistants, 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 that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels) http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.

Nationally developed guidelines, such as the [ACR's Appropriateness Criteria](#), should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org) websites. 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 measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry, the 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. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

The Qualified Medical Physicist should assist facilities in understanding and developing policies and procedures to minimize risks to patients, personnel, and medical staff from CT procedures. The Qualified Medical Physicist should assist the Radiation Safety Officer in evaluating the radiation risks to occupationally exposed individuals as well as members of the public who may be affected by the CT equipment, which can include radiation shielding calculation and evaluation.

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Collaborative Committee – members represent their societies in the initial and final revision of this technical standard

ACR

Maxwell R. Amurao, PhD, MBA, Co-Chair
Douglas E. Pfeiffer, MS, FACR, FAAPM, Co-Chair
Mary Ann Keenan, DMP

AAPM

Jessica B. Clements, MS
Tyler S. Fisher, MS
Michael F. Tkacik, MS

Committee on Practice Parameters and Technical Standards – Medical Physics

(ACR Committee responsible for sponsoring the draft through the process)

Maxwell R. Amurao, PhD, MBA, Chair
Charles M. Able, MS
Ishtiaq H. Bercha, MSc
Caridad Borrás, DSc, FACR, FAAPM, FIOMP
Chee-Wai Cheng, PhD, FAAPM
William R. Geiser, MS
Mary Ann Keenan, DMP
Ralph P. Lieto, MS, FACR, FAAPM

Lijun Ma, PhD, FAAPM
Jonathon A. Nye, PhD
Matthew A. Pacella, MS, FACR
William Pavlicek, PhD
Douglas E. Pfeiffer, MS, FACR, FAAPM
Premavathy Rassiah, PhD
Thomas G. Ruckdeschel, MS
Christopher J. Watchman, PhD

Richard A. Geise, PhD, FACR, FAAPM, Chair, Commission on Medical Physics
Jacqueline A. Bello, MD, FACR, Chair, Commission on Quality and Safety
Matthew S. Pollack, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee

Beth A. Schueler, PhD, FACR, FAAPM, Chair
Amy L. Kotsenas, MD, Co-Chair

Mary Ann Keenan, DMP
Douglas E. Pfeiffer, MS, FACR

Comments Reconciliation Committee

Maxwell R. Amurao, PhD, MBA
Jacqueline A. Bello, MD, FACR
Jessica B. Clements, MS
Tyler S. Fisher, MS
Richard A. Geise, PhD, FACR, FAAPM
William T. Herrington, MD, FACR

Matthew S. Pollack, MD, FACR
William F. Sensakovic, PhD
Timothy L. Swan, MD, FACR, FSIR
Michael F. Tkacik, MS
Roland Wong, ScM

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- 1998 (Resolution 14)
- Revised 2002 (Resolution 21)
- Amended 2006 (Resolution 16g, 17)
- Revised 2007 (Resolution 14)
- Revised 2012 (Resolution 34)

As of May 2015, all practice parameters and technical standards that are collaborative with **only** the American Association 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 displayed below

- Revised 2017 (BOC/CSC); effective August 1, 2017