ACR–ASNR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF COMPUTED TOMOGRAPHY (CT) OF THE HEAD

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 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 practice parameter was revised collaboratively by the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), and the Society for Pediatric Radiology (SPR).

Computed tomography (CT) is a technology that produces cross-sectional images of the body using X-rays. CT is used extensively in imaging of the head. This practice parameter outlines the principles for performing high-quality CT imaging of the head in pediatric and adult patients. There should be an effort to minimize radiation exposure, particularly in children. An alternate modality should be considered when possible.

CT of the head is superior to magnetic resonance imaging (MRI) for rapid assessment in emergent/urgent settings, particularly for the evaluation of osseous structures, acute hemorrhage, and calcifications. These findings can be important for the initial identification of an abnormality or for refinement of a differential diagnosis. CT of the brain is sufficient and diagnostic in many clinical circumstances, such as in acute trauma, intracranial hemorrhage, evaluation of ventricle size, and selected postoperative follow-up. However, CT is less useful than MRI for many conditions that require higher contrast resolution, such as neoplastic, infectious, ischemic, or inflammatory conditions affecting the cranial nerves, brain parenchyma, and meninges. In combination with the clinical history and physical examination findings, CT of the brain is a useful screening tool for indications such as acute mental status change, seizure, acute neurologic deficit, acute headache, and nonacute headache with neurologic findings. While MRI is a more sensitive modality for detection of parenchymal abnormalities, CT can be useful to screen for mass effect and addition of intravenous contrast may increase sensitivity for masses, infection, or vascular abnormalities when MRI is not available. For further information see the ACR Manual on Contrast Media [1].

II. INDICATIONS

Indications for CT of the brain include, but are not limited to, the following:

A. Primary Indications
1. Acute head trauma [2-6]
2. Suspected acute intracranial hemorrhage [7-9]
3. Follow-up for known intracranial hemorrhages
4. Detection or evaluation of calcification [10]
5. Postoperative evaluation following intracranial surgery [11]
6. Mental status change [12], including drug toxicity [12-15]
7. Headache [16, 17]
8. Acute neurologic deficits [18], including cranial nerve dysfunction [19-21] and ataxia [22]
9. Intracranial infection [23-27]
10. Hydrocephalus [28, 29], including shunt malfunctions or shunt revisions [28]
11. Congenital skull and brain lesions (such as, but not limited to, craniosynostosis, macrocephaly, and microcephaly) [7, 30, 31]
12. Suspected mass or tumor [32-36], including brain herniation syndromes [3, 4] and increased intracranial pressure [4, 5]
13. CT guidance, image integration, and 3-D planning [37-45]
14. Skull lesions (such as, but not limited to, fibrous dysplasia, Paget disease, histiocytosis, osteolytic lesions, and skeletal tumors)
15. Abusive head trauma and postmortem forensic investigations [15, 46-49]
16. Seizures [50-54]

B. Secondary Indications (when MRI is unavailable or contraindicated, or if the supervising physician determines CT to be appropriate [54])
1. Epilepsy [50-54]
2. Neurodegenerative disease [55-58]
3. Developmental delay [29, 59]
4. Evaluating psychiatric disorder [60]
5. Autoimmune conditions

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [61].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [62].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for CT of the head should provide sufficient information to demonstrate the medical necessity of the examination and allow for the proper performance and interpretation of the examination.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). The provision of additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

A. The supervising physician must have adequate understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician performing CT interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the examination.

   General Considerations

   CT protocols for brain imaging should be designed to answer the specific clinical question. The supervising physician should be familiar with the indications for each examination, relevant patient history, and potential adverse reactions to contrast media. The supervising physician should be familiar with how individual CT settings affect radiation dose and image quality, including field of view, collimation, pitch, automated exposure control, image reconstruction algorithms such as iterative reconstruction [63] and, when available, newer scanning techniques such as dual-energy CT or photon-counting CT [64, 65]. The goal of CT scanning is to obtain diagnostic information from images of sufficient quality. Protocols should be optimized to deliver the lowest dose required to achieve appropriate image quality and should be reviewed and updated as needed in light of new clinically applicable developments [65-74].

B. Brain Imaging

   CT brain imaging is performed for the evaluation of a variety of pathologies that require appropriate techniques for acquisition and viewing. CT brain imaging may be performed with a sequential single-slice technique, multislice helical (spiral) protocol, or multidetector multislice algorithm [75, 76]. The mechanism of detection includes conventional energy integrating detector (EID) and newer photon counting technologies. Use of these techniques is dependent on clinical indication, scanner capability, and image quality requirements. For CT of the brain, contiguous or overlapping axial slices should be acquired with a slice thickness of no greater than 5 mm. In addition to directly acquired axial images, reformatted images in coronal, sagittal, true axial, or other more complex planes may be constructed from the axial data set to answer specific clinical questions. Additionally, axial reconstructed images should be presented with at least 2 different kernels, using both a brain/soft tissue and bone kernel. Brain images should be reviewed at dedicated workstations and with window settings appropriate for demonstrating brain, bone, and soft-tissue abnormalities, including hemorrhage.

   For further information, see the American Association of Physicists in Medicine Routine (AAPM) Adult Head (Brain) Protocols [77].

C. Contrast Studies

   Certain indications require administration of IV contrast media or intrathecal contrast (eg, cisternography, ventriculography) during imaging of the brain. Contrast administration should be performed using appropriate injection protocols and be in accordance with the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [78]. Cerebrospinal fluid contrast administration requires the use of nonionic agents appropriate for intrathecal use and should be performed using appropriate protocols as outlined in the ACR–ASNR–SPR Practice Parameter for the Performance of Myelography and Cisternography [79].

D. Advanced Applications

   Postprocessing by physicians, radiologic technologists, or appropriately trained staff is recommended. Furthermore, images may be manipulated to allow selective visualization of specific tissues, such as in CT perfusion, CT volumetry, CT angiography (CTA)/venography, multimodality image fusion, and neuronavigational mapping techniques. Such applications are better performed with helical, volume, dual-energy, or photon-counting data sets rather than routine axial sequential data [37, 43, 74, 80-96]. Also see the ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging [97] and the ACR–ASNR–SPR Practice Parameter for the Performance and Interpretation of Cervicocerebral Computed Tomography Angiography (CTA) [98]. Pre- and postcontrast imaging are not recommended in pediatric patients for most indications.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [99].

VI. EQUIPMENT SPECIFICATIONS

For specific issues regarding CT quality control, see the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [62].

Equipment monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [100].

A. Performance Standards

To achieve acceptable clinical CT scans of the brain, the CT scanner should meet or exceed the following specifications:

1. Scan times: per slice or image not more than 2 seconds
2. Slice thickness: acquired slice thickness should be 2 mm or less, whereas reconstructed slice thickness should be 5 mm or less
3. Interscan delay: no more than 4 seconds; however, this may be longer if intravascular contrast media is not used (not applicable with helical scanners)
4. Limiting spatial resolution: must be measured to verify that it meets the unit manufacturer’s specifications. Limiting spatial resolution should be >;10 lp/cm for a display field of view <;24 cm
5. Table pitch: no greater than 2 for most CT scanners; pitch may be increased for dual-energy scanners for sole evaluation of bone anatomy (craniofacial)
6. For advanced applications (eg, perfusion imaging or CTA, cine-capable scanners are preferable with tube rotation ≤1 second and continuous cine imaging ≥60 seconds. See the ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging [97].

B. Patient monitoring equipment and facilities for cardiopulmonary resuscitation, including vital signs monitoring equipment and support equipment, should be immediately available.

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages or sizes in the patient populations. Radiologists, technologists, and staff members should be available to assist with procedures, patient monitoring, and patient support. A written policy should be in place for dealing with emergencies, such as cardiopulmonary arrest.

VII. 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

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.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

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).

When possible, CT imaging of the head should consider the following to minimize radiation dose and maintain image quality:

1. Center the patient in the gantry [101]
2. Remove unnecessary objects from the patient
3. Use of iterative reconstruction technique, if available

Higher radiation doses are typically needed to assess the brain parenchyma compared with specific structures such as the bones, facial soft tissues, and ventricles. As such, dose-minimization CT techniques should be used for imaging scenarios in which the brain parenchyma itself does not need to be evaluated, such as in the evaluation of shunt placement/malfunction, routine paranasal sinus evaluation, and craniosynostosis in the pediatric population [102].

Diagnostic Reference Levels and Achievable Doses are national benchmarks for radiation protection and optimization that provide a comparison for facilities in order to review techniques and determine whether acceptable image quality can be achieved at lower doses. Published levels are available [103]. For further information, see the ACR–AAPM–SPR Practice Parameter for Diagnostic Reference Levels and Achievable Doses in Medical X-Ray Imaging [104].

Attention to dose is particularly important but also particularly challenging in the pediatric population, when age- and size-specific protocols should be considered [105]. Photon counting CT can achieve 80% reduction in ionizing radiation exposure while achieving the same or superior image quality when compared with EID CT. MRI may be an alternative to CT in monitoring the size of intracranial fluid collections, such as the ventricles in shunted hydrocephalus, size of arachnoid cysts, or size of nonacute subdural collections. Rapid-MRI protocols to include susceptibility and diffusion-weighted imaging sequences have been used in the setting of acute stroke. For trauma, accessibility and technical limitations may preclude the use of MRI. MRI is more sensitive in detecting areas of parenchymal brain injury that may not be obvious on CT [106], and may also be appropriate for follow-up of findings on CT [107].

The use of shields for radiation protection of superficial organs, such as the lens of the eye or the thyroid gland, is controversial. The goal of shielding is to limit unnecessary irradiation to nontarget, radiosensitive organs, and bismuth shields, which have been shown to reduce anterior surface dose, are available. However, shielding has several disadvantages, not the least of which is unpredictable results when combined with automated exposure control features. Alternative methods, such as a global reduction in dose together with iterative reconstruction to reduce image noise, as mentioned above in Section IV.A, can achieve the same goal. For further information, see the AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT Scanning [108].

In addition to CT radiation safety and quality control, appropriateness studies, and utilization review, a facilitating best practices for CT brain imaging should also be considered and encouraged as part of a comprehensive continuous quality improvement program [46, 109-117].

VIII. 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 Position Statement on Quality Control and Improvement, Safety, Infection Control and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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