Revised 2010 (Resolution 12)*

ACR–ASNR PRACTICE GUIDELINE FOR THE PERFORMANCE OF COMPUTED TOMOGRAPHY (CT) OF THE BRAIN

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 guideline was developed collaboratively by the American College of Radiology (ACR) and the American Society of Neuroradiology (ASNR).

Computed tomography (CT) is a technology extensively used in neuroradiology that produces cross-sectional displays using ionizing radiation to generate images resulting from X-ray absorption by the specific tissues examined. CT offers a high degree of utility in the examination of the brain. This guideline outlines the principles for performing high-quality CT imaging of the brain in pediatric and adult patients, including advanced applications such as CT perfusion, CT volumetry, CT angiography, and CT venography.

II. INDICATIONS

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

A. Primary Indications

1. Acute head trauma.
2. Suspected acute intracranial hemorrhage.

3. Vascular occlusive disease or vasculitis (including use of CT angiography and/or venography).
4. Aneurysm evaluation.
5. Detection or evaluation of calcification.
6. Immediate postoperative evaluation following surgical treatment of tumor, intracranial hemorrhage, or hemorrhagic lesions.
7. Treated or untreated vascular lesions.
8. Suspected shunt malfunctions**,** or shunt revisions.
9. Mental status change.
10. Increased intracranial pressure.
11. Headache.
12. Acute neurologic deficits.
13. Suspected intracranial infection.
14. Suspected hydrocephalus.
15. Congenital lesions (such as, but not limited to, craniosynostosis, macrocephaly, and micro-cephaly).
16. Evaluating psychiatric disorders.
17. Brain herniation.
18. Suspected mass or tumor.

B. Secondary Indications

1. When magnetic resonance imaging (MRI) imaging is unavailable or contraindicated, or if the supervising physician deems CT to be appropriate.
2. Diplopia.
3. Cranial nerve dysfunction.
4. Seizures.
5. Apnea.
6. Syncope.
7. Ataxia.
8. Suspicion of neurodegenerative disease.
9. Developmental delay.
10. Neuroendocrine dysfunction.
11. Encephalitis.
12. Drug toxicity.
13. Cortical dysplasia, and migration anomalies or other morphologic brain abnormalities.

For the pregnant or potentially pregnant patient, see the ACR Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation.

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT).

IV. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician should be familiar with relevant ancillary studies that the patient may have undergone. (See the ACR Practice Guideline for Communication of Diagnostic Imaging Findings.) The physician performing CT interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the examination.

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

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). 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's scope of practice requirements. (ACR Resolution 35, adopted in 2006)

A. 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, potential adverse reactions to contrast media, exposure factors, window and center settings, field of view, collimation, slice intervals, slice spacing (table increment) or pitch, and image reconstruction algorithms**.** Protocols should be reviewed and updated periodically to optimize the examination.

B. Brain Imaging

CT brain imaging may be performed with a sequential single-slice technique, multislice helical (spiral) protocol, or multidetector multislice algorithm. For CT of the brain, contiguous or overlapping axial slices should be acquired with a slice thickness of no greater than 5 mm. In the setting of trauma, images should be obtained and/or reviewed at window settings appropriate for demonstrating brain and bone abnormalities as well as

small subdural hematomas and soft tissue lesions (subdural windows). For imaging of the cranial base, an axial slice thickness as thin as possible, but no greater than 3 mm with spiral techniques and 2 mm with multidetector and nonspiral techniques, should be used for 2D reformatting or for 3D reconstruction.

C. Contrast Studies

Certain indications require administration of intravenous (IV) contrast media or intrathecal contrast (e.g., cisternography) during imaging of the brain. Intravenous contrast enhancement should be performed using appropriate injection protocols and in accordance with the ACR Practice Guideline for the Use of Intravascular Contrast Media. Cerebrospinal fluid (CSF) contrast administration requires use of nonionic agents approved for intrathecal use and should be performed with regard to applicable guidelines as outlined in the ACR–ASNR Practice Guideline for the Performance of Myelography and Cisternography.

D. Advanced Applications

In addition to directly acquired axial images, reformatted images in coronal, sagittal, or other more complex planes may be constructed from the axial data set to answer specific clinical questions, or the images may be manipulated to allow selective visualization of specific tissues such as in CT perfusion, CT volumetry, CT angiography, or CT venography. Such applications are better performed with helical data sets using very thin slice thickness and overlapping reconstruction rather than routine axial sequential data. See the ACR–ASNR Practice Guideline for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Guideline for Communication of Diagnostic Imaging Findings.

VI. EQUIPMENT SPECIFICATIONS

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: minimum slice thickness 2 mm or less.

3. Interscan delay: not more than 4 seconds (may be longer if intravascular contrast media is not used).

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 <24 cm display field of view (DFOV).

5. Table pitch: no greater than 2:1 for most CT scanners.

6. For advanced applications (e.g., perfusion imaging or CTA), cine-capable scanners are preferable with tube rotation ≤1 second and continuous cine imaging ≥60 seconds. See the ACR–ASNR Practice Guideline for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging.

B. Patient monitoring equipment and facilities for cardiopulmonary resuscitation, including vital signs monitoring equipment, 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 able 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, 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. 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)

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

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

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

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 Guidelines and Standards Committee of the Commission on Neuroradiology in collaboration with the Subcommittee on Standards and Guidelines of the ASNR.

Principal Drafter: John E. Jordan, MD

ACR Guidelines and Standards Committee
Suresh K. Mukherji, MD, FACR, Chair
Jacqueline A. Bello, MD, FACR
Mark H. Depper, MD
Carol A. Dolinskas, MD, FACR
Sachin Gujar, MD
John E. Jordan, MD
Stephen A. Kieffer, MD, FACR
Edward J. O'Brien, Jr., MD, FACR
Jeffrey R. Petrella, MD
John L. Ulmer, MD
R. Nick Bryan, MD, PhD, FACR, Chair, Commission

ASNR Guidelines Committee
Suresh K. Mukherji, MD, FACR, Chair
John D. Barr, MD
Jacqueline A. Bello, MD, FACR
Carol A. Dolinskas, MD, FACR
Kavita K. Erickson, MD
Scott H. Faro, MD
Blaise V. Jones, MD
John E. Jordan, MD
Edward E. Kassel, MD, FACR
Stephen A. Kieffer, MD, FACR
Eric J. Russell, MD, FACR
Jeffrey A. Stone, MD
Robert W. Tarr, MD
Patrick A. Turski, MD, FACR

Comments Reconciliation Committee
Michael M. Raskin, MD, MPH, JD, MBA, FACR, Chair
Kimberly E. Applegate, MD, MS, FACR
Howard B. Fleishon, MD, MMM, FACR
John E. Jordan, MD
Alan D. Kaye, MD, FACR
Paul A. Larson, MD, FACR
Lawrence A. Liebscher, MD, FACR
Carolyn C. Meltzer, MD, FACR
Suresh K. Mukherji, MD, FACR
Christopher J. Roth, MD
Michael I. Rothman, MD
Lawrence N. Tanenbaum, MD, FACR

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

1. *Quality Assurance for Diagnostic Imaging Equipment.* Bethesda, Md.: National Council on Radiation Protection (NCRP); 1988. NCRP Report 99.
2. Alberico RA, Loud P, Pollina J, Greco W, Patel M, Klufas R. Thick-section reformatting of thinly collimated helical CT for reduction of skull base-related artifacts. *AJR* 2000;175:1361-1366.
3. Calzado A, Rodriguez R, Munoz A. Quality criteria implementation for brain and lumbar spine CT examinations. *Br J Radiol* 2000;73:384-395.
4. Castillo M. Contrast enhancement in primary tumors of the brain and spinal cord. *Neuroimaging Clin N Am* 1994;4:63-80.
5. Chamberlain MC. Pediatric AIDS: a longitudinal comparative MRI and CT brain imaging study. *J Child Neurol* 1993; 8:175-181.
6. Eastwood JD, Lev MH, Azhari T, et al. CT perfusion scanning with deconvolution analysis: pilot study in patients with acute middle cerebral artery stroke. *Radiology* 2002;222:227-236.
7. Ertl-Wagner B, Eftimov L, Blume J, et al. Cranial CT with 64-, 16-, 4-single-slice CT systems-comparison of image quality and posterior fossa artifacts in routine brain imaging with standard protocols. *Eur Radiol* 2008;18:1720-1726.
8. Ezzeddine MA, Lev MH, McDonald CT, et al. CT angiography with whole brain perfused blood volume imaging: added clinical value in the assessment of acute stroke. *Stroke* 2002;33:959-966.

9. Faerber E. *Cranial Computed Tomography in Infants and Children*. Philadelphia, Pa: Lippincott, Williams & Wilkins; 1986.
10. Fleischmann D, Rubin GD, Paik DS, et al. Stair-step artifacts with single versus multiple detector-row helical CT. *Radiology* 2000;216:185-196.
11. Flodmark O. Neuroradiology of selected disorders of the meninges, calvarium, and venous sinuses. *AJNR* 1992;13:483-491.
12. Friedman JA, Goerss SJ, Meyer FB, et al. Volumetric quantification of Fisher Grade 3 aneurysmal subarachnoid hemorrhage: a novel method to predict symptomatic vasospasm on admission computerized tomography scans. *J Neurosurg* 2002;97:401-407.
13. Furukawa M, Kashiwagi S, Matsunaga N, Suzuki M, Kishimoto K, Shirao S. Evaluation of cerebral perfusion parameters measured by perfusion CT in chronic cerebral ischemia: comparison with xenon CT. *J Comput Assist Tomogr* 2002;26:272-278.
14. Gentry LR. Imaging of closed head injury. *Radiology* 1994;191:1-17.
15. Griffiths PD, Wilkinson ID, Patel MC, et al. Acute neuromedical and neurosurgical admissions. Standard and ultrafast MR imaging of the brain compared with cranial CT. *Acta Radiol* 2000;41:401-409.
16. Hakimelahi R, Gonzalez RG. Neuroimaging of ischemic stroke with CT and MRI: advancing towards physiology-based diagnosis and therapy. *Cardiovasc Ther* 2009;7:29-48.
17. Harden SP, Dey C, Gawne-Cain ML. Cranial CT of the unconscious adult patient. *Clin Radiol* 2007;62:404-415.
18. Hoeffner EG, Quint DJ, Peterson B, Rosenthal E, Goodsitt M. Development of a protocol for coronal reconstruction of the maxillofacial region from axial helical CT data. *Br J Radiol* 2001;74:323-327.
19. Hollister LE, Boutros N. Clinical use of CT and MR scans in psychiatric patients. *J Psychiatry Neurosci* 1991;16:194-198.
20. Hope JK, Wilson JL, Thomson FJ. Three-dimensional CT angiography in the detection and characterization of intracranial berry aneurysms. *AJNR* 1996;17:439-445.
21. Iwasaki S, Nakagawa H, Fukusumi A, et al. Identification of pre- and postcentral gyri on CT and MR images on the basis of the medullary pattern of cerebral white matter. *Radiology* 1991;179:207-213.
22. Jayaraman MV, Mayo-Smith WW. Multi-detector CT angiography of the intra-cranial circulation: normal anatomy and pathology with angiographic correlation. *Clin Radiol* 2004;59:690-698.
23. Jhaveri KS, Saini S, Levine LA, et al. Effect of multislice CT technology on scanner productivity. *AJR* 2001;177:769-772.
24. Jones TR, Kaplan RT, Lane B, Atlas SW, Rubin GD. Single- versus multi-detector row CT of the brain: quality assessment. *Radiology* 2001;219:750-755.
25. Jordan JE, Enzmann DR. Encephalitis. *Neuroimaging Clin N Am* 1991; 1:17-38.
26. Jordan MJ, Lightfoote JB, Jordan JE. Quality outcomes of reinterpretation of brain CT imaging studies by subspecialty experts in neuroradiology. *J Natl Med Assoc* 2006;98:1326-1328.
27. Kornreich L, Shapira A, Horev G, Danziger Y, Tyano S, Mimouni M. CT and MR evaluation of the brain in patients with anorexia nervosa. *AJNR* 1991;12:1213-1216.
28. Laissy JP, Soyer P, Parlier C, et al. Persistent enhancement after treatment for cerebral toxoplasmosis in patients with AIDS: predictive value for subsequent recurrence. *AJNR* 1994;15:1773-1778.
29. Lallemand DP, Brasch RC, Char DH, Norman D. Orbital tumors in children. Characterization by computed tomography. *Radiology* 1984;151:85-88.
30. Lindgren A, Norrving B, Rudling O, Johansson BB. Comparison of clinical and neuroradiological findings in first-ever stroke. A population-based study. *Stroke* 1994; 25:1371-1377.
31. Lipper MH, Kishore PR, Enas GG, Domingues da Silva AA, Choi SC, Becker DP. Computed tomography in the prediction of outcome in head injury. *AJR* 1985;144:483-486.
32. Mahesh M, Scatarige JC, Cooper J, Fishman EK. Dose and pitch relationship for a particular multislice CT scanner. *AJR* 2001;177:1273-1275.
33. Marks MP, Napel S, Jordan JE, Enzmann DR. Diagnosis of carotid artery disease: preliminary experience with maximum-intensity-projection spiral CT angiography. *AJR* 1993;160:1267-1271.
34. Marshall LF, Marshall SB, Klauber MR, et al. The diagnosis of head injury requires a classification based on computed axial tomography. *J Neurotrauma* 1992;9 Suppl 1:S287-292.
35. Matsumoto M, Kodama N, Endo Y, et al. Dynamic 3D-CT angiography. *AJNR* 2007;28:299-304.
36. Matsumoto M, Kodama N, Sakuma J, et al. 3D-CT arteriography and 3D-CT venography: the separate demonstration of arterial-phase and venous-phase on 3D-CT angiography in a single procedure. *AJNR* 2005;26:635-641.
37. Maytal J, Bienkowski RS, Patel M, Eviatar L. The value of brain imaging in children with headaches. *Pediatrics* 1995;96:413-416.
38. McCrohan JL, Patterson JF, Gagne RM, Goldstein HA. Average radiation doses in a standard head examination for 250 CT systems. *Radiology* 1987; 63:263-268.
39. Mullins ME, Schaefer PW, Sorensen AG, et al. CT and conventional and diffusion-weighted MR imaging in acute stroke: study in 691 patients at presentation to the emergency department. *Radiology* 2002;224:353-360.
40. Murayama K, Katada K, Nakane M. et al. Whole-brain perfusion CT performed with a prototype 256-detector row CT system: initial experience. *Radiology* 2009;250:202-211.
41. Prabhakar R, Haresh KP, Ganesh T, Joshi RC, Julka PK, Rath GK. Comparison of computed tomography

and magnetic resonance based target volume in brain tumors. *J Cancer Res Ther* 2007;3:121-123.
42. Pressman BD, Tourje EJ, Thompson JR. An early CT sign of ischemic infarction: increased density in a cerebral artery. *AJR* 1987;149:583-586.
43. Prokop M. Multislice CT angiography. *Eur J Radiol* 2000;36:86-96.
44. Ray CE, Jr., Mafee MF, Friedman M, Tahmoressi CN. Applications of three-dimensional CT imaging in head and neck pathology. *Radiol Clin North Am* 1993;31:181-194.
45. Roberts HC, Dillon WP, Furlan AJ, et al. Computed tomographic findings in patients undergoing intra-arterial thrombolysis for acute ischemic stroke due to middle cerebral artery occlusion: results from the PROACT II trial. *Stroke* 2002;33:1557-1565.
46. Sase S, Honda M, Kushida T, Seiki Y, Machida K, Shibata I. Quantitative cerebral blood flow calculation method using white matter lambda in xenon CT. *J Comput Assist Tomogr* 2002;26:471-478.
47. Savoiardo M, Bracchi M, Passerini A, Visciani A. The vascular territories in the cerebellum and brainstem: CT and MR study. *AJNR* 1987;8:199-209.
48. Schramm P. High-concentration contrast media in neurological multidetector-row CT applications: implications for improved patient management in neurology and neurosurgery. *Neuroradiology* 2007;49 Suppl 1:S35-45.
49. Siironen J, Porras M, Varis J, Poussa K, Hernesniemi J, Juvela S. Early ischemic lesion on computed tomography: predictor of poor outcome among survivors of aneurysmal subarachnoid hemorrhage. *J Neurosurg* 2007;107:1074-1079.
50. Snow RB, Zimmerman RD, Gandy SE, Deck MD. Comparison of magnetic resonance imaging and computed tomography in the evaluation of head injury. *Neurosurgery* 1986;18:45-52.
51. Somford DM, Nederkoorn PJ, Rutgers DR, Kappelle LJ, Mali WP, van der Grond J. Proximal and distal hyperattenuating middle cerebral artery signs at CT: different prognostic implications. *Radiology* 2002;223:667-671.
52. Stringer WA, Hasso AN, Thompson JR, Hinshaw DB, Jordan KG. Hyperventilation-induced cerebral ischemia in patients with acute brain lesions: demonstration by xenon-enhanced CT. *AJNR* 1993;14:475-484.
53. Sze G, Shin J, Krol G, Johnson C, Liu D, Deck MD. Intraparenchymal brain metastases: MR imaging versus contrast-enhanced CT. *Radiology* 1988;168:187-194.
54. Takase K, Sawamura Y, Igarashi K, et al. Demonstration of the artery of Adamkiewicz at multi- detector row helical CT. *Radiology* 2002;223:39-45.
55. Tan JS, Tan KL, Lee JC, Wan CM, Leong JL, Chan LL. Comparison of eye lens dose on neuroimaging protocols between 16- and 64-section multidetector CT: achieving the lowest possible dose. *Am J Neuroradiol* 2009;30:373-377.
56. Taphoorn MJ, Heimans JJ, Kaiser MC, de Slegte RG, Crezee FC, Valk J. Imaging of brain metastases. Comparison of computerized tomography (CT) and magnetic resonance imaging (MRI). *Neuroradiology* 1989;31:391-395.
57. Wintermark M, Maeder P, Thiran JP, Schnyder P, Meuli R. Quantitative assessment of regional cerebral blood flows by perfusion CT studies at low injection rates: a critical review of the underlying theoretical models. *Eur Radiol* 2001;11:1220-1230.
58. Wolf M, Ziegengeist S, Michalik M, Bornholdt F, Michalik S, Meffert B. Classification of brain tumours by CT-image Walsh spectra. *Neuroradiology* 1990;32:464-466.

*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
2004 (Resolution 32)
Amended 2006 (Resolution 17, 35)
Revised 2009 (Resolution 27)
Revised 2010 (Resolution 12)