Revised 2020 (Resolution 42)*

ACR–ASNR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE AND INTERPRETATION OF CERVICOCEREBRAL COMPUTED TOMOGRAPHY ANGIOGRAPHY (CTA)

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).

Cervicocerebral computed tomography angiography (CTA) is a proven and useful procedure for the detection and characterization of vascular diseases and of vascular anatomy relevant to the treatment of extravascular disorders [1]. CTA may be used as the primary modality for detecting disease or as an adjunctive tool for characterizing known disease or assessing changes over time. Whenever possible, magnetic resonance angiography (MRA) should be considered as an alternative to CTA to reduce radiation exposure, especially in the pediatric and vulnerable populations [2,3]. Although it is not possible to detect all cerebrovascular abnormalities using CTA, adherence to the following practice parameter will maximize the probability of their detection and optimize patient safety.

CTA is a medical imaging technology that exposes patients to ionizing radiation. It should only be performed under the supervision of a physician with the necessary training in radiation biology and protection to optimize patient safety. Medical physicists and trained technical staff must be available.

CTA should be performed only for a valid medical indication and with the minimum exposure that provides the image quality necessary for adequate diagnostic information.

CTA is primarily performed to assess the heart, arteries, or veins. It requires, at a minimum, a thin-section CT acquisition coupled with a power injection of intravenous (IV) iodinated contrast medium. Three-dimensional rendering and multiplanar reformations are important components of CTA examinations.

II. INDICATIONS

Indications for CTA of the head and neck vessels include, but are not limited to, the diagnosis, characterization, and/or surveillance of:

1. Arterial aneurysms or pseudoaneurysms, venous varices, and dissections [2-10]
2. Ischemic stroke, transient ischemic attacks, vasospasm, and thromboembolism, including collateral assessment [9,11-24]
3. Acute neurologic, head and neck, and cervical spine hemorrhage [25-29]
4. Atherosclerotic steno-occlusive disease, including atherosclerotic plaque localization and characterization [1,30-39]
5. Nonatherosclerotic, noninflammatory vasculopathy, including radiation vasculopathy
6. Vasculitis and collagen vascular diseases [40]
7. Traumatic vascular injuries [3,35,41-49]
8. Venous and dural sinus thrombosis and stenosis when performed as a dedicated CT venogram (CTV) [50-52]
9. Vascular malformations and fistulas [53]
10. Pulsatile tinnitus [54]
11. Vascular anatomic variants [35,55]
12. Evaluation for vascular intervention and follow-up (percutaneous and surgical) [56-70]
13. Tumors of vascular origin, with rich vascular supply or involving vascular structures [68,71-75].
14. Surgical and radiation therapy localization, planning, and neuronavigation [70,76]
15. Dynamic/positional CTA to assess for vascular compression vertebrobasilar insufficiency (bow-hunter's syndrome and Eagle syndrome) [77,78]
16. Brain death [79]
17. Cervical and upper thoracic spine injuries in the setting of trauma
18. Postsurgical/posttreatment vascular complications

For certain indications, such as cerebral aneurysms and vasospasm, it may be appropriate to limit CTA to include only the head to avoid unnecessary radiation to the patient.

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [80].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [81].

A. Physician

Examinations must be performed under the supervision of and interpreted by a physician who has the following qualifications:

The physician should meet the criteria listed in the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) and in the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media and should be trained in radiation safety [81,82].

1. The physician is responsible for reviewing indications for the examination and for specifying the parameters of image acquisition; the route, volume, timing, type, and rate of contrast injection; and the method of image reconstruction and archival. The physician should monitor the quality of the images, be aware of potential artifacts [83], and interpret the study. Interpreting physicians must have knowledge of the benefits and risks of the procedures. Knowledge of the head and neck anatomy, including the vascular anatomy, and diseases of the intracranial and extracranial cerebrovascular system and their treatment is required.

2. Physicians meeting the aforementioned criteria additionally must have knowledge of the spectrum of nonvascular abnormalities presenting on CT scans. They should be capable of identifying and characterizing important nonvascular abnormalities that may be visualized on CTA, such as neoplasia, sequelae of infection, trauma, noninfectious inflammatory diseases, congenital anomalies, and normal anatomic variants, and any other abnormalities that may affect patient care and might necessitate treatment or further characterization through additional diagnostic testing.

3. The physician should be familiar with the use of 3-D processing workstations and be capable of performing or directing creation of 3-D renderings, multiplanar reformations, and measurements of vessel dimensions.

4. The physician should work with a Qualified Medical Physicist to optimize site-specific CTA scan protocols, when possible.

B. Technologist

The technologist should have the responsibility of patient comfort, preparing and positioning the patients for the CT examination, monitoring the patient during the examination, and obtaining the CT data in a manner prescribed by the supervising physician. For the IV administration of contrast material for CTA, qualifications for technologists performing IV injections should be in compliance with current ACR policy and existing operating procedures or manuals at the imaging facility. The technologist should perform the regular quality control testing of the CT system under the supervision of a medical physicist (ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media) [82].

1. The technologist performing CT examinations should be certified by the American Registry of Radiologic Technologists or have an unrestricted state license with documented training and experience in CT.

IV. SPECIFICATIONS OF THE EXAMINATION

CTA is a broad term that may refer to evaluation of arterial vessels, known as CTA, or evaluation of venous structures, known as CT venography (CTV). The equipment and contrast used for these examinations is the same. The scan protocols differ in the time delay to scanning following the injection of contrast.

The written or electronic request for a cervicocerebral CTA 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. Patient Selection and Preparation

Patients without absolute contraindication to the administration of iodinated contrast media are candidates for cervicocerebral CTA. In cases of relative contraindication to the administration of iodinated contrast medium, measures to reduce the possibility of contrast medium reactions or nephrotoxicity should be followed to the extent that the patient's condition allows, as defined in the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media, or an alternative vascular imaging modality should be considered, eg, MRA [82,84].

When possible, patients should be well hydrated, and IV access should be established. A 20-gauge or larger antecubital IV catheter should be placed ideally on the right side to accommodate an optimal rate of 4 or 5 mL/s of iodinated contrast media. Smaller catheters that can withstand the prescribed injection rates can be used, and lower injection rates may be used for pediatric patients. All catheters used for the CTA examination should first be tested with a rapidly injected bolus of sterile saline to ensure that the venous access is secure and can accommodate the rapid bolus, minimizing the risk of contrast medium extravasations. The injection site should be monitored by medical personnel trained in the rapid recognition of IV extravasations. Department procedures for care of IV extravasations should be documented and applied if necessary.

B. CT Equipment

The use of a multidetector-row CT scanner is preferred for CTA. A complete gantry rotation should be no greater than 1 second, and preferably less. The scanner must be capable of detecting and reliably diagnosing pathology in the adjacent structures and end organs of the vessels.

A contrast medium power injector that allows programming of both the volume and flow rate must be used for head and neck CTA examinations.

Capability of creating multiplanar reformations, curved planar reformations, maximum-intensity projections, volume renderings, and/or shaded surface displays should be available for CTAs and applied to the appropriate study. The direct measurement of vascular diameters and, when appropriate, path lengths should also be available.

C. Examination Technique

Prior to acquiring the CTA, a noncontrast head CT (NECT) may be obtained, depending on the clinical suspicion, presentation, and acuity, for detecting mural or extravascular hemorrhage, mapping of arterial calcification, or localization of the anatomy of interest. Similarly, once contrast has already been administered for the CTA, a delayed contrast-enhanced head CT (CECT) can be of value to detect areas of delayed/parenchymal enhancement, slow-flow lesions, and/or spot sign not captured on the CTA. Section thickness for these additional CT acquisitions is application dependent but should not exceed 5 mm. The radiation exposure to the patient should be minimized within the limits of acceptable image quality, including optimization of peak kilovoltage (kVp) and mAs [85,86]. In infants and children, weight- or age-appropriate guidelines should be used for acceptable CT radiation exposure to reflect the "as low as reasonably achievable" (ALARA) principle. If available, dose modulation and iterative reconstruction approaches should be used, with appropriate targeted signal-to-noise ratio [87,88].

Because of substantial variations in the time required for an IV injection of nonionic contrast medium (iodine, 300-370 mg/mL) to reach the target vascular anatomy, an assessment of patient-specific circulation time is frequently required, especially for arterial imaging, although not mandatory. Circulation timing can be performed using one of the following techniques [89]:

1. Intravenous injection of a small test bolus (eg, 10-15 mL) of contrast medium at the same rate and through the same access that will be used for the CTA followed by acquisition of sequential cine CT images at the level of the artery or vein of interest. The rate and intensity of enhancement of the lumen of interest are then used to create a time density curve. The peak of the curve is used to calculate the scanning delay postinjection. A perfusion CT series performed before the CTA can be used similarly to a test bolus for determining the timing of the CTA acquisition.

2. The use of automated or semiautomated triggering software based on monitoring of the attenuation within the vessel of interest (or a great vessel such as the aorta) by the CT scanner following initiation of the full dose of contrast media injection. The CTA is automatically started when the enhancement in the vessel reaches a predetermined operator-selected level.

3. For CTV, administration of nonionic contrast medium with a 40- 50 second prescanning delay, or a 30 second delay after the arterial bolus time, should allow adequate opacification of the venous structures minimizing flow artifacts.

Ideally the administration of iodinated contrast media for the CTA should be performed with a minimum flow rate of 4 mL/s in any patient weighing 50 kg or more. Higher flow rates up to 6 mL/s are frequently required for larger patients, and in general, higher flow rates are required for shorter acquisitions. In children, contrast medium dosing should be scaled to body weight. Injection rate should be scaled similarly and preferably delivered via powered injection. For young children and infants, a 22- or 24-gauge IV catheter may be the only option, and a 2 mL/s injection rate may be reasonable for these patients. For patients under 50 kg, a dose of 2 mL/kg should be considered. In summary, contrast injection parameters should be modified on an individual patient basis, and the volume of contrast medium should be selected with consideration of the patient's weight and comorbidities that might increase the risk of nephrotoxicity. When performing cervicocerebral CTA, a right-arm injection is preferable to a left-arm injection to avoid artifacts from undiluted contrast medium in the left brachiocephalic vein. When possible, a bolus of saline following the iodinated contrast medium injection may reduce the volume of contrast medium required to achieve adequate vascular opacification.

The cervicocerebral CTA acquisition should be performed with a section thickness of 1.5 mm or less, depending on the vascular territory to be assessed. The scan should be reconstructed with overlapping sections. For many indications, such as intracranial aneurysms, vasospasm, and venous/dural sinus thrombosis, CTA imaging only needs to include the head. When CTA imaging of the neck is performed, such as in the setting of trauma/cervical fractures, the acquisition should at least cover the aortic arch, the origin and cervical course of the subclavian and carotid arteries, and proximal subclavian arteries, through the skull base (eg, the floor of the Sella). For many indications, such as stroke imaging, the acquisition should be extended through the Circle of Willis and may be extended up to the cranial vertex. In the pediatric population, anatomic coverage should be strictly limited to the vascular segments of interest. Automated tube voltage selection can also be employed in conjunction with tube current modulation when available.

Postprocessing of the CTA by either physicians, radiologic technologists, or appropriately trained staff to provide multiplanar reformations and/or 3-D renderings is recommended [90]. Volume renderings, maximum-intensity projections, shaded surface displays, and curved planar reformations must be created by a person with knowledge of both cervicocerebral vascular anatomy and pathology to avoid misrepresenting normal regions as diseased and vice versa. Segmentation of the CT data through a variety of manual and automated means may facilitate vascular visualization and measurement of stenosis, but it must be performed with care to avoid excluding key regions of the anatomy or creating pseudolesions. Pertinent measurements of vascular dimensions should be performed [91].

When applying the North American Symptomatic Carotid Endarterectomy Trial (NASCET) method for evaluation of cervical internal carotid artery stenosis, it is important for the interpreting physician to take into consideration that the denominator measurement needs to be done well beyond the tapering bulb, which tapers over a long distance, and should only be done where the vessel walls are parallel. An alternate method uses the residual lumen diameter measured in millimeters. This approach has been validated against the NASCET methodology and has been shown to be reproducible, to be easy to implement, and to provide similar information [90,92-97].

D. Interpretation

Cervicocerebral CTAs are preferentially interpreted on equipment that allows stacked dynamic paging of the primary transverse and the reformatted CTA sections. A complete interpretation includes review of all images, including the scout and the transverse CT sections (source images) and, as indicated, multiplanar/curved reformations, volume renderings, maximum-intensity projections, and other images produced during postprocessing. On occasion, the interpreting physician will personally create postprocessed images documenting important findings that are essential to the interpretation of the study [98]. These images should be archived with the patient's original study or other postprocessed images. Interpretation of the cervicocerebral CTA includes an assessment of the patency and caliber of the carotid and vertebral arteries, their origins, the carotid bifurcations, the intracranial arteries, possible occlusion, dissection, stenosis, and aneurysmal dilatation. To the extent that venous structures are adequately opacified on CTA images, as opposed to a dedicated delayed CTV, evaluation of images for venous pathology is also necessary. The visible and adequately opacified veins should be commented on when appropriate. Interpretation of dedicated cervicocerebral CTV includes an assessment of the patency and caliber of the dural venous sinuses, cortical veins, and internal jugular veins. The visible and adequately opacified arteries should be commented on when appropriate.

The visible regional anatomy and pathology should be commented on when appropriate. In the setting of suspected traumatic injury, the soft issues surrounding the vasculature and adjacent bony structures in the cervical region should be assessed. Comparison with prior studies should be performed when appropriate.

V. DOCUMENTATION

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

In addition to examining the cervicocerebral vascular structures of interest, the CTA sections should be examined for clinically relevant extravascular abnormalities. These abnormalities should be described in the formal report of the examination.

VI. EQUIPMENT SPECIFICATIONS

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

For diagnostic quality CTA, the CT scanner should meet or exceed the following specifications:

1. Cervicocerebral CTA should be performed on a multidetector CT (MDCT) scanner, preferably with greater than or equal to four active detector rows.

2. Gantry rotation: 1 second or less for cervicocerebral CTA.
3. Tube heat capacity that allows for a single ≥10-second acquisition.
4. Section thickness: no greater than 1.5 mm.

To maximize information available from the CT scan and thus derive the full diagnostic benefit for the patient following x-ray irradiation, any CT scanner used for CTA must allow display and interpretation of the full 12 bits (from −1,000 to 3,095 Hounsfield units) of attenuation information. Additionally, the display field of view must be sufficient to allow an assessment of the vasculature of interest, the end-organ, and adjacent tissues. Dual-energy CTA can be obtained when available to decrease total patient radiation dose, lower contrast administration, distinguish contrast from hemorrhage and calcium, and reduce hardware artifacts [101-104].

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 and sizes in the patient population.

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).

Utilization of iterative image reconstruction techniques, when available, is recommended to reduce image noise and artifacts, thereby allowing significant dose reduction.

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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REFERENCES

1. Brown DL, Hoffman SN, Jacobs TL, Gruis KL, Johnson SL, Chernew ME. CT angiography is cost-effective for confirmation of internal carotid artery occlusions. J Neuroimaging 2008;18:355-9.
2. Hellinger JC, Pena A, Poon M, Chan FP, Epelman M. Pediatric computed tomographic angiography: imaging the cardiovascular system gently. Radiol Clin North Am 2010;48:439-67, x.
3. Stence NV, Fenton LZ, Goldenberg NA, Armstrong-Wells J, Bernard TJ. Craniocervical arterial dissection in children: diagnosis and treatment. Curr Treat Options Neurol 2011;13:636-48.
4. Chen W, Wang J, Xin W, Peng Y, Xu Q. Accuracy of 16-row multislice computed tomographic angiography for assessment of small cerebral aneurysms. Neurosurgery 2008;62:113-21; discussion 21-2.
5. Dammert S, Krings T, Moller-Hartmann W, et al. Detection of intracranial aneurysms with multislice CT: comparison with conventional angiography. Neuroradiology 2004;46:427-34.
6. Jayaraman MV, Mayo-Smith WW, Tung GA, et al. Detection of intracranial aneurysms: multi-detector row CT angiography compared with DSA. Radiology 2004;230:510-8.
7. McKinney AM, Palmer CS, Truwit CL, Karagulle A, Teksam M. Detection of aneurysms by 64-section multidetector CT angiography in patients acutely suspected of having an intracranial aneurysm and comparison with digital subtraction and 3D rotational angiography. AJNR Am J Neuroradiol 2008;29:594-602.
8. Teksam M, McKinney A, Casey S, Asis M, Kieffer S, Truwit CL. Multi-section CT angiography for detection of cerebral aneurysms. AJNR Am J Neuroradiol 2004;25:1485-92.
9. Mehan WA, Jr., Romero JM, Hirsch JA, et al. Unruptured intracranial aneurysms conservatively followed with serial CT angiography: could morphology and growth predict rupture? J Neurointerv Surg 2013.
10. Wang GX, Gong MF, Wen L, et al. Computed Tomography Angiography Evaluation of Risk Factors for Unstable Intracranial Aneurysms. World Neurosurg 2018;115:e27-e32.
11. Chaudhary SR, Ko N, Dillon WP, et al. Prospective evaluation of multidetector-row CT angiography for the diagnosis of vasospasm following subarachnoid hemorrhage: a comparison with digital subtraction angiography. Cerebrovasc Dis 2008;25:144-50.
12. Coutts SB, Lev MH, Eliasziw M, et al. ASPECTS on CTA source images versus unenhanced CT: added value in predicting final infarct extent and clinical outcome. Stroke 2004;35:2472-6.
13. Josephson SA, Bryant SO, Mak HK, Johnston SC, Dillon WP, Smith WS. Evaluation of carotid stenosis using CT angiography in the initial evaluation of stroke and TIA. Neurology 2004;63:457-60.
14. Tan JC, Dillon WP, Liu S, Adler F, Smith WS, Wintermark M. Systematic comparison of perfusion-CT and CT-angiography in acute stroke patients. Ann Neurol 2007;61:533-43.
15. Torres-Mozqueda F, He J, Yeh IB, et al. An acute ischemic stroke classification instrument that includes CT or MR angiography: the Boston Acute Stroke Imaging Scale. AJNR Am J Neuroradiol 2008;29:1111-7.

16. Wintermark M, Uske A, Chalaron M, et al. Multislice computerized tomography angiography in the evaluation of intracranial aneurysms: a comparison with intraarterial digital subtraction angiography. J Neurosurg 2003;98:828-36.

17. Yoon DY, Lim KJ, Choi CS, Cho BM, Oh SM, Chang SK. Detection and characterization of intracranial aneurysms with 16-channel multidetector row CT angiography: a prospective comparison of volume-rendered images and digital subtraction angiography. AJNR Am J Neuroradiol 2007;28:60-7.

18. Chatzikonstantinou A, Krissak R, Fluchter S, et al. CT angiography of the aorta is superior to transesophageal echocardiography for determining stroke subtypes in patients with cryptogenic ischemic stroke. Cerebrovasc Dis 2012;33:322-8.

19. Furtado AD, Adraktas DD, Brasic N, et al. The triple rule-out for acute ischemic stroke: imaging the brain, carotid arteries, aorta, and heart. AJNR Am J Neuroradiol 2010;31:1290-6.

20. Greenberg ED, Gold R, Reichman M, et al. Diagnostic accuracy of CT angiography and CT perfusion for cerebral vasospasm: a meta-analysis. AJNR Am J Neuroradiol 2010;31:1853-60.

21. Ritter MA, Poeplau T, Schaefer A, et al. CT angiography in acute stroke: does it provide additional information on occurrence of infarction and functional outcome after 3 months? Cerebrovasc Dis 2006;22:362-7.

22. Wintermark M, Sanelli PC, Albers GW, et al. Imaging recommendations for acute stroke and transient ischemic attack patients: A joint statement by the American Society of Neuroradiology, the American College of Radiology, and the Society of NeuroInterventional Surgery. AJNR Am J Neuroradiol 2013;34:E117-27.

23. Sundaram S, Kannoth S, Thomas B, Sarma PS, Sylaja PN. Collateral Assessment by CT Angiography as a Predictor of Outcome in Symptomatic Cervical Internal Carotid Artery Occlusion. AJNR Am J Neuroradiol 2017;38:52-57.

24. Varadharajan S, Saini J, Acharya UV, Gupta AK. Computed tomography angiography in acute stroke (revisiting the 4Ps of imaging). Am J Emerg Med 2016;34:282-7.

25. Kim J, Smith A, Hemphill JC, 3rd, et al. Contrast extravasation on CT predicts mortality in primary intracerebral hemorrhage. AJNR Am J Neuroradiol 2008;29:520-5.

26. Romero JM, Artunduaga M, Forero NP, et al. Accuracy of CT angiography for the diagnosis of vascular abnormalities causing intraparenchymal hemorrhage in young patients. Emerg Radiol 2009;16:195-201.

27. Chakraborty S, Alhazzaa M, Wasserman JK, et al. Dynamic characterization of the CT angiographic 'spot sign'. PLoS One 2014;9:e90431.

28. Demchuk AM, Dowlatshahi D, Rodriguez-Luna D, et al. Prediction of haematoma growth and outcome in patients with intracerebral haemorrhage using the CT-angiography spot sign (PREDICT): a prospective observational study. Lancet Neurol 2012;11:307-14.

29. Rodriguez-Luna D, Dowlatshahi D, Aviv RI, et al. Venous phase of computed tomography angiography increases spot sign detection, but intracerebral hemorrhage expansion is greater in spot signs detected in arterial phase. Stroke 2014;45:734-9.

30. Bartlett ES, Walters TD, Symons SP, Fox AJ. Diagnosing carotid stenosis near-occlusion by using CT angiography. AJNR Am J Neuroradiol 2006;27:632-7.

31. Prokop M, Waaijer A, Kreuzer S. CT angiography ofthe carotid arteries. JBR-BTR 2004;87:23-9.

32. Randoux B, Marro B, Marsault C. Carotid Artery Stenosis: Competition between CT Angiography and MR Angiography. AJNR Am J Neuroradiol 2004;25:663-4; author reply 64.

33. Wintermark M, Ko NU, Smith WS, Liu S, Higashida RT, Dillon WP. Vasospasm after subarachnoid hemorrhage: utility of perfusion CT and CT angiography on diagnosis and management. AJNR Am J Neuroradiol 2006;27:26-34.

34. Wintermark M, Meuli R, Browaeys P, et al. Comparison of CT perfusion and angiography and MRI in selecting stroke patients for acute treatment. Neurology 2007;68:694-7.

35. Barazangi N, Wintermark M, Lease K, Rao R, Smith W, Josephson SA. Comparison of computed tomography angiography and transesophageal echocardiography for evaluating aortic arch disease. J Stroke Cerebrovasc Dis 2011;20:436-42.

36. Magge R, Lau BC, Soares BP, et al. Clinical risk factors and CT imaging features of carotid atherosclerotic plaques as predictors of new incident carotid ischemic stroke: a retrospective cohort study. AJNR Am J Neuroradiol 2013;34:402-9.

37. Romero JM, Babiarz LS, Forero NP, et al. Arterial wall enhancement overlying carotid plaque on CT angiography correlates with symptoms in patients with high grade stenosis. Stroke 2009;40:1894-6.

38. Wintermark M, Jawadi SS, Rapp JH, et al. High-resolution CT imaging of carotid artery atherosclerotic plaques. AJNR Am J Neuroradiol 2008;29:875-82.

39. Sun PP, Feng PY, Wang Q, Shen SS. Angiography with the 256-multislice spiral computed tomography and its application in evaluating atherosclerotic plaque and cerebral ischemia. Medicine (Baltimore) 2018;97:e11408.

40. Schmidt WA. Imaging in vasculitis. Best Pract Res Clin Rheumatol 2013;27:107-18.

41. Berne JD, Norwood SH, McAuley CE, Villareal DH. Helical computed tomographic angiography: an excellent screening test for blunt cerebrovascular injury. J Trauma 2004;57:11-7; discussion 17-9.

42. Nguyen-Huynh MN, Wintermark M, English J, et al. How accurate is CT angiography in evaluating intracranial atherosclerotic disease? Stroke 2008;39:1184-8.

43. van Prehn J, Muhs BE, Pramanik B, et al. Multidimensional characterization of carotid artery stenosis using CT imaging: a comparison with ultrasound grading and peak flow measurement. Eur J Vasc Endovasc Surg 2008;36:267-72.

44. Roberts DJ, Chaubey VP, Zygun DA, et al. Diagnostic accuracy of computed tomographic angiography for blunt cerebrovascular injury detection in trauma patients: a systematic review and meta-analysis. Ann Surg 2013;257:621-32.

45. Langner S, Fleck S, Kirsch M, Petrik M, Hosten N. Whole-body CT trauma imaging with adapted and optimized CT angiography of the craniocervical vessels: do we need an extra screening examination? AJNR Am J Neuroradiol 2008;29:1902-7.

46. Methodius-Ngwodo WC, Burkett AB, Kochupura PV, Wellons ED, Fuhrman G, Rosenthal D. The role of CT angiography in the diagnosis of blunt traumatic thoracic aortic disruption and unsuspected carotid artery injury. Am Surg 2008;74:580-5; discussion 85-6.

47. Tessler RA, Nguyen H, Newton C, Betts J. Pediatric penetrating neck trauma: Hard signs of injury and selective neck exploration. J Trauma Acute Care Surg 2017;82:989-94.

48. Todnem N, Hardigan T, Banerjee C, Alleyne CH, Jr. Cephalad Migration of Intradural Bullet from Thoracic Spine to Cervical Spine. World Neurosurg 2018;119:6-9.

49. Ugalde IT, Claiborne MK, Cardenas-Turanzas M, Shah MN, Langabeer JR, 2nd, Patel R. Risk Factors in Pediatric Blunt Cervical Vascular Injury and Significance of Seatbelt Sign. West J Emerg Med 2018;19:961-69.

50. Leach JL, Fortuna RB, Jones BV, Gaskill-Shipley MF. Imaging of cerebral venous thrombosis: current techniques, spectrum of findings, and diagnostic pitfalls. Radiographics 2006;26 Suppl 1:S19-41; discussion S42-3.

51. Taschner CA, Leclerc X, Lucas C, Pruvo JP. Computed tomography angiography for the evaluation of carotid artery dissections. Front Neurol Neurosci 2005;20:119-28.

52. Vertinsky AT, Schwartz NE, Fischbein NJ, Rosenberg J, Albers GW, Zaharchuk G. Comparison of multidetector CT angiography and MR imaging of cervical artery dissection. AJNR Am J Neuroradiol 2008;29:1753-60.

53. Singh R, Gupta V, Ahuja C, Kumar A, Mukherjee KK, Khandelwal N. Role of time-resolved-CTA in intracranial arteriovenous malformation evaluation at 128-slice CT in comparison with digital subtraction angiography. Neuroradiol J 2018;31:235-43.

54. Xu S, Ruan S, Liu S, Xu J, Gong R. CTA/V detection of bilateral sigmoid sinus dehiscence and suspected idiopathic intracranial hypertension in unilateral pulsatile tinnitus. Neuroradiology 2018;60:365-72.

55. Sivaraju L, Mani S, Prabhu K, Daniel RT, Chacko AG. Three-dimensional computed tomography angiographic study of the vertebral artery in patients with congenital craniovertebral junction anomalies. Eur Spine J 2017;26:1028-38.

56. Chen W, Yang Y, Xing W, Qiu J, Peng Y. Sixteen-row multislice computed tomography angiography in the diagnosis and characterization of intracranial aneurysms: comparison with conventional angiography and intraoperative findings. J Neurosurg 2008;108:1184-91.

57. Dehdashti AR, Binaghi S, Uske A, Regli L. Comparison of multislice computerized tomography angiography and digital subtraction angiography in the postoperative evaluation of patients with clipped aneurysms. J Neurosurg 2006;104:395-403.

58. Katano H, Kato K, Umemura A, Yamada K. Perioperative evaluation of carotid endarterectomy by 3D-CT angiography with refined reconstruction: preliminary experience of CEA without conventional angiography. Br J Neurosurg 2004;18:138-48.

59. Lev MH, Farkas J, Rodriguez VR, et al. CT angiography in the rapid triage of patients with hyperacute stroke to intraarterial thrombolysis: accuracy in the detection of large vessel thrombus. J Comput Assist Tomogr 2001;25:520-8.

60. Ozsvath RR, Casey SO, Lustrin ES, Alberico RA, Hassankhani A, Patel M. Cerebral venography: comparison of CT and MR projection venography. AJR Am J Roentgenol 1997;169:1699-707.

61. Papke K, Kuhl CK, Fruth M, et al. Intracranial aneurysms: role of multidetector CT angiography in diagnosis and endovascular therapy planning. Radiology 2007;244:532-40.

62. Rosenthal ES, Schwamm LH, Roccatagliata L, et al. Role of recanalization in acute stroke outcome: rationale for a CT angiogram-based "benefit of recanalization" model. AJNR Am J Neuroradiol 2008;29:1471-5.

63. Wetzel SG, Kirsch E, Stock KW, Kolbe M, Kaim A, Radue EW. Cerebral veins: comparative study of CT venography with intraarterial digital subtraction angiography. AJNR Am J Neuroradiol 1999;20:249-55.

64. Bal S, Bhatia R, Shobha N, et al. Stroke- on- Awakening: Safety of CT-CTA Based Selection for Reperfusion Therapy. Can J Neurol Sci 2014;41:182-6.

65. Fiebach JB, Al-Rawi Y, Wintermark M, et al. Vascular occlusion enables selecting acute ischemic stroke patients for treatment with desmoteplase. Stroke 2012;43:1561-6.

66. Gonzalez RG, Furie KL, Goldmacher GV, et al. Good outcome rate of 35% in IV-tPA-treated patients with computed tomography angiography confirmed severe anterior circulation occlusive stroke. Stroke 2013;44:3109-13.

67. Nambiar V, Sohn SI, Almekhlafi MA, et al. CTA collateral status and response to recanalization in patients with acute ischemic stroke. AJNR Am J Neuroradiol 2014;35:884-90.

68. Schaefer PW, Yoo AJ, Bell D, et al. CT angiography-source image hypoattenuation predicts clinical outcome in posterior circulation strokes treated with intra-arterial therapy. Stroke 2008;39:3107-9.

69. Storey C, Barry J, Adkins W, Nanda A, Saenz-Cuellar H. A Morphometric Analysis for the Feasibility of Percutaneous Translacerum Access of the Internal Carotid Artery Based on Computed Tomography Angiography. World Neurosurg 2019;121:e925-e30.

70. Wada K, Nawashiro H, Ohkawa H, Arimoto H, Takeuchi S, Mori K. Feasibility of the combination of 3D CTA and 2D CT imaging guidance for clipping microsurgery of anterior communicating artery aneurysm. Br J Neurosurg 2015;29:229-36.

71. Goodman DN, Hoh BL, Rabinov JD, Pryor JC. CT angiography before embolization for hemorrhage in head and neck cancer. AJNR Am J Neuroradiol 2003;24:140-2.

72. Kramer M, Vairaktaris E, Nkenke E, Schlegel KA, Neukam FW, Lell M. Vascular mapping of head and neck: computed tomography angiography versus digital subtraction angiography. J Oral Maxillofac Surg 2008;66:302-7.

73. Sims JR, Rordorf G, Smith EE, et al. Arterial occlusion revealed by CT angiography predicts NIH stroke score and acute outcomes after IV tPA treatment. AJNR Am J Neuroradiol 2005;26:246-51.

74. Swieton D, Kaszubowski M, Szyndler A, et al. Visualizing Carotid Bodies With Doppler Ultrasound Versus CT Angiography: Preliminary Study. AJR Am J Roentgenol 2017;209:1348-52.

75. Xiao Z, Zheng Y, Li J, Chen D, Liu F, Cao D. Four-dimensional CT angiography (4D-CTA) in the evaluation of juvenile nasopharyngeal angiofibromas: comparison with digital subtraction angiography (DSA) and surgical findings. Dentomaxillofac Radiol 2017;46:20170171.

76. Srinivasan VM, Schafer S, Ghali MG, Arthur A, Duckworth EA. Cone-beam CT angiography (Dyna CT) for intraoperative localization of cerebral arteriovenous malformations. J Neurointerv Surg 2016;8:69-74.

77. Jost GF, Dailey AT. Bow hunter's syndrome revisited: 2 new cases and literature review of 124 cases. Neurosurg Focus 2015;38:E7.

78. Chuang WC, Short JH, McKinney AM, Anker L, Knoll B, McKinney ZJ. Reversible left hemispheric ischemia secondary to carotid compression in Eagle syndrome: surgical and CT angiographic correlation. AJNR Am J Neuroradiol 2007;28:143-5.

79. Suarez-Kelly LP, Patel DA, Britt PM, et al. Dead or alive? New confirmatory test using quantitative analysis of computed tomographic angiography. J Trauma Acute Care Surg 2015;79:995-1003; discussion 03.

80. American College of Radiology. ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Pregnant-Pts.pdf?la=en. Accessed February 1, 2019.

81. American College of Radiology. ACR practice parameter for performing and interpreting diagnostic computed tomography (CT). Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Perf-Interpret.pdf?la=en. Accessed February 1, 2019.

82. American College of Radiology. ACR–SPR practice parameter for the use of intravascular contrast media. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/IVCM.pdf?la=en. Accessed February 1, 2019.

83. Kim JJ, Dillon WP, Glastonbury CM, Provenzale JM, Wintermark M. Sixty-four-section multidetector CT angiography of carotid arteries: a systematic analysis of image quality and artifacts. AJNR Am J Neuroradiol 2010;31:91-9.

84. Oleinik A, Romero JM, Schwab K, et al. CT angiography for intracerebral hemorrhage does not increase risk of acute nephropathy. Stroke 2009;40:2393-7.

85. Loftus ML, Minkowitz S, Tsiouris AJ, Min RJ, Sanelli PC. Utilization guidelines for reducing radiation exposure in the evaluation of aneurysmal subarachnoid hemorrhage: A practice quality improvement project. AJR Am J Roentgenol 2010;195:176-80.

86. Siegel MJ, Hildebolt C, Bradley D. Effects of automated kilovoltage selection technology on contrast-enhanced pediatric CT and CT angiography. Radiology 2013;268:538-47.

87. Komlosi P, Zhang Y, Leiva-Salinas C, et al. Adaptive statistical iterative reconstruction reduces patient radiation dose in neuroradiology CT studies. Neuroradiology 2014;56:187-93.

88. Singh S, Kalra MK, Shenoy-Bhangle AS, et al. Radiation dose reduction with hybrid iterative reconstruction for pediatric CT. Radiology 2012;263:537-46.

89. Lell M, Tomandl BF, Anders K, Baum U, Nkenke E. Computed tomography angiography versus digital subtraction angiography in vascular mapping for planning of microsurgical reconstruction of the mandible. Eur Radiol 2005;15:1514-20.

90. Sparacia G, Bencivinni F, Banco A, Sarno C, Bartolotta TV, Lagalla R. Imaging processing for CT angiography of the cervicocranial arteries: evaluation of reformatting technique. Radiol Med 2007;112:224-38.

91. Wintermark M, Glastonbury C, Tong E, et al. Semi-automated computer assessment of the degree of carotid artery stenosis compares favorably to visual evaluation. J Neurol Sci 2008;269:74-9.

92. Bartlett ES, Symons SP, Fox AJ. Correlation of carotid stenosis diameter and cross-sectional areas with CT angiography. AJNR Am J Neuroradiol 2006;27:638-42.

93. Bartlett ES, Walters TD, Symons SP, Aviv RI, Fox AJ. Classification of carotid stenosis by millimeter CT angiography measures: effects of prevalence and gender. AJNR Am J Neuroradiol 2008;29:1677-83.
94. Bartlett ES, Walters TD, Symons SP, Fox AJ. Quantification of carotid stenosis on CT angiography. AJNR Am J Neuroradiol 2006;27:13-9.
95. Bartlett ES, Walters TD, Symons SP, Fox AJ. Carotid stenosis index revisited with direct CT angiography measurement of carotid arteries to quantify carotid stenosis. Stroke 2007;38:286-91.
96. Bucek RA, Puchner S, Haumer M, Reiter M, Minar E, Lammer J. CTA quantification of internal carotid artery stenosis: application of luminal area vs. luminal diameter measurements and assessment of inter-observer variability. J Neuroimaging 2007;17:219-26.
97. Cademartiri F, Nieman K, van der Lugt A, et al. Intravenous contrast material administration at 16-detector row helical CT coronary angiography: test bolus versus bolus-tracking technique. Radiology 2004;233:817-23.
98. Leong JL, Batra PS, Citardi MJ. Three-dimensional computed tomography angiography of the internal carotid artery for preoperative evaluation of sinonasal lesions and intraoperative surgical navigation. Laryngoscope 2005;115:1618-23.
99. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf?la=en. Accessed February 1, 2019.
100. American College of Radiology. ACR–AAPM technical standard for diagnostic medical physics performance monitoring of computed tomography (CT) equipment. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Equip.pdf?la=en. Accessed February 1, 2019.
101. Zhao L, Li F, Zhang Z, et al. Assessment of an advanced virtual monoenergetic reconstruction technique in cerebral and cervical angiography with third-generation dual-source CT: Feasibility of using low-concentration contrast medium. Eur Radiol 2018;28:4379-88.
102. Ferda J, Novak M, Mirka H, et al. The assessment of intracranial bleeding with virtual unenhanced imaging by means of dual-energy CT angiography. Eur Radiol 2009;19:2518-22.
103. Jiang XY, Zhang SH, Xie QZ, et al. Evaluation of Virtual Noncontrast Images Obtained from Dual-Energy CTA for Diagnosing Subarachnoid Hemorrhage. AJNR Am J Neuroradiol 2015;36:855-60.
104. Kamalian S, Lev MH, Pomerantz SR. Dual-Energy Computed Tomography Angiography of the Head and Neck and Related Applications. Neuroimaging Clin N Am 2017;27:429-43.

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