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

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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 angiography (CTA) of the head and neck 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. When possible, magnetic resonance angiography (MRA) can 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.

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 hemorrhage in the head or neck [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, 41-50]
8. Venous and dural sinus thrombosis [51-53]
9. Vascular malformations and fistulas [54]
10. Pulsatile tinnitus [55]
11. Vascular anatomic variants [35, 56]
12. Evaluation for vascular intervention and follow-up (percutaneous and surgical) [57-71]
13. Tumors of vascular origin, with rich vascular supply or involving vascular structures [69, 72-76]
14. Surgical and radiation therapy localization, planning, and neuronavigation [71, 77]
15. To assess for vascular compression (eg bow-hunter's syndrome and Eagle syndrome) [78, 79]
16. Brain death in certain jurisdictions, especially when used in conjunction with other testing [80]
17. 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 [81].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [82].

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 [82, 83].

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 [84], 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 intravenous (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) [83].

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. When referring to evaluation of arterial vessels, CTA is commonly used as an acronym. When CTA is used for evaluation of venous structures, it is typically denoted as a CT venogram (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 CTA of the head and neck 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)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Patient Selection and Preparation

Patients without absolute contraindication to the administration of iodinated contrast media are candidates for CTA of the head and neck. 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, for example, MRA [83, 85].

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 (and preferably proximal to the wrist) to accommodate an optimal rate of 4–5 mL/s of iodinated contrast media. Small 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.

IV. SPECIFICATIONS OF THE EXAMINATION

B. CT Equipment

The use of a multidetector-row CT scanner is required for CTA. The scanner must be capable of detecting and reliably displaying pathology in the adjacent structures and end organs of the vessels. Please refer to section VI for further equipment details.

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.

IV. SPECIFICATIONS OF THE EXAMINATION

C. Examination Technique

Before acquiring the CTA, a noncontrast head CT and/or noncontrast neck CT may be obtained, depending on the clinical suspicion, presentation, and acuity, for detecting 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 and/or neck CT can be of value to detect areas of delayed/parenchymal enhancement, slow-flow lesions, spot sign not captured on the CTA, and/or for collateral assessment. 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 [86, 87]. 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 [88, 89].

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 [90]:

1. IV 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 may be used. The CT automatically starts when the enhancement in the vessel reaches a predetermined operator-selected level. An individualized posttrigger delay may optimize vessel opacification [91].
3. For CTV, administration of nonionic contrast medium with a 40–50-second prescanning delay, or up to 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 up to 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 contrast associated acute kidney injury. When performing CTA of the head and neck, a right-arm injection is preferable to a left-arm injection to avoid artifacts from undiluted contrast medium in the left brachiocephalic vein, and reflux of contrast due to venous narrowing at the level of the sternum. 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 CTA head and neck 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 cerebral venous thrombosis, imaging only needs to include the head. When CTA imaging of the neck is performed, such as in the setting of trauma, 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.

Utilization of iterative image reconstruction techniques, when available, is recommended to reduce image noise and artifacts, thereby allowing significant dose reduction [92]. Utilization of AI/deep learning techniques for image reconstruction may allow further dose reductions [93].

Postprocessing of the CTA by either physicians, radiologic technologists, or appropriately trained staff to provide multiplanar reformations and/or 3-D renderings is recommended [94]. Volume renderings, maximum-intensity projections, shaded surface displays, and curved planar reformations must be created by a person with knowledge of both head and neck 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 [95].

IV. SPECIFICATIONS OF THE EXAMINATION

D. Interpretation

CTAs of the head and neck 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. The use of 3D reconstruction techniques (such as volume rendering or MIPs) is a required component of the examination. On occasion, the interpreting physician will personally create postprocessed images documenting important findings that are essential to the interpretation of the study [96]. These images should be archived with the patient's original study or other postprocessed images.

Interpretation of the head and neck 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 head and neck 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. The soft tissues and bony structures in the cervical region should be assessed in addition to the vessels. Bone kernel reconstruction images can be generated when appropriate. Comparison with previous studies should be performed when appropriate.

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 [94, 97-102].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [103].

In addition to examining the head and neck 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 [104].

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

1. Head and neck CTA should be performed on a multidetector CT (MDCT) scanner, with at least 16 active detector rows, with 64 or more detector rows being ideal.
2. Gantry rotation: 1 second or less for head and neck CTA.
3. Tube heat capacity that allows for a single ≥10-second acquisition.
4. Capability of acquiring a section thickness of less than or equal to 1.5 mm.
5. Capability of helical or volume acquisitions with variable pitch.
6. Ability to create multiplanar images.
7. Image acquisition and reconstruction capabilities that allow for spatial resolutions of ≥ 8 lp/cm.

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 (or possibly 16 bits for scans obtained on photon counting CT scanners). 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 [105-108]. Photon counting CT, when available, may provide increased quality by decreased noise and fewer artifacts in addition to the capability of material decomposition [109, 110].

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

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals in accordance with ALARA principles. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by applicable state, local, or other relevant regulatory agencies and accrediting bodies, as appropriate. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol, using body habitus or other customized method when such guidance is available.

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.

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).

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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