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The American College of Radiology will periodically define new practice guidelines and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Quality and Safety as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The practice guidelines and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline and technical standard by those entities not providing these services is not authorized.

2010 (Resolution 20)\*

## **ACR–ASNR PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF CERVICOCEREBRAL COMPUTED TOMOGRAPHY ANGIOGRAPHY (CTA)**

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### **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).

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 better characterizing known disease or assessing changes in disease state over time. While it is not possible to detect all abnormalities using CTA, adherence to the following guideline will maximize the probability of their detection.

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 protection to optimize examination safety. Medical physicists and trained technical staff must be available.

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

## II. DEFINITION

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

## III. 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 and venous aneurysms or pseudo aneurysms [2-8].
2. Stroke and vasospasm [9-15].
2. Atherosclerotic occlusive disease [16-20].
3. Nonatherosclerotic, noninflammatory vasculopathy.
4. Traumatic injuries to arteries and veins [21-23].
5. Arterial dissection and intramural hematoma [24,25].
6. Venous and dural sinus thrombosis.
7. Congenital vascular anomalies.
8. Vascular anatomic variants.
9. Vascular interventions (percutaneous and surgical) [26-33].
10. Vasculitis and collagen vascular diseases.
11. Vascular infection.
12. Head and neck tumors of vascular origin, with rich vascular supply or invading vascular structures [34-37].

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

## IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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

### A. Physician

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

1. The physician should meet the criteria listed in the [ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography \(CT\)](#) and in the [ACR–SPR Practice Guideline for the Use of Intravascular Contrast Media](#), and should be trained in radiation safety.
2. 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 storage. The physician should monitor the quality of the images and interpret the study. Interpreting physicians must have knowledge of the anatomy of the head and neck and diseases of the cerebrovascular system and their treatment.
3. Nonradiologist 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 manifest on CT angiograms, including neoplasia, sequela of infection, trauma, noninfectious inflammatory diseases, congenital anomalies and normal anatomic variants, and any other abnormalities that might necessitate treatment or further characterization through additional diagnostic testing.
4. The physician should be familiar with the use of 3D processing workstations and be capable of performing or directing a technologist in creation of 3D renderings, multiplanar reformations, and measurements of vessel dimensions.

### B. Technologist

1. The technologist should have the responsibility for 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 administration of contrast material for CTA, qualifications for technologists performing intravenous 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 Guideline for the Use of Intravascular Contrast Media](#) (ACR Resolution 51, 2001 – revised in 2007, Resolution 38)]

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

## V. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a cervicocerebral CTA 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 scope of practice requirements. (ACR Resolution 35, adopted in 2006)

### A. Patient Selection and Preparation

Patients without absolute contraindication to the administration of iodinated contrast media are candidates for cervicocerebral CTA. If a relative contraindication to the administration of iodinated contrast medium is present, 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 Guideline for the Use of Intravascular Contrast Media](#), or an alternative vascular imaging modality should be considered, e.g., magnetic resonance angiography (MRA).

When possible, patients should be well hydrated, and intravenous access should be established. A 20-gauge or larger antecubital intravenous (IV) catheter should be placed ideally on the right side, to accommodate an optimal rate of 4 or 5 ml per second of iodinated contrast media. All catheters used for the CTA 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.

### B. CT Equipment

The use of a multi-detector-row CT scanner is preferred for CTA. Helical CT acquisition is mandatory 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 powered contrast medium injector that allows programming of both the volume and flow rate must be used for head and neck CTA examinations.

A workstation capable of creating multiplanar reformations, maximum-intensity projections, and volume renderings or shaded surface displays should be available for CTAs, and applicable to the appropriate study. The workstation should also allow the direct measurement of vascular diameters and, when appropriate, path lengths.

### C. Examination Technique

Prior to acquiring the CTA, an unenhanced helical CT acquisition may be necessary for detecting mural or extravascular hemorrhage, mapping of arterial calcification, or localization of the anatomy of interest. The section thickness for this preliminary CT acquisition is application dependent. Ideally it should be the same thickness as the CTA but definitely should not exceed 5 mm. The radiation exposure to the patient should be minimized within the limits of acceptable image quality, including optimization of kVp and mAs. If infants and children are being imaged, there should be written guidelines for acceptable CT radiation exposure, including weight-appropriate or age-appropriate guidelines to reflect the as-low-as-reasonably-achievable (ALARA) principle. Dose modulation approaches can be used, with appropriate targeted signal-to-noise ratio.

Because of substantial variations in the time required for an intravenous contrast medium injection to reach the target vascular anatomy, an assessment of patient-specific circulation time is frequently required, although not mandatory. Circulation timing can be performed using 2 techniques [38]:

1. Intravenous injection of a small test bolus (e.g., 10 to 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 post injection.

2. The use of automated triggering software based on monitoring of the attenuation within the vessel of interest 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.

The administration of iodinated contrast media for the CTA should ideally be performed with a minimum flow rate of 4 ml per second in any patient weighing 50 or more kilograms. Higher flow rates up to 6 ml per second or greater are frequently required for larger patients, and in general higher flow rates are required for shorter acquisitions. Therefore, contrast injection parameters should be modified on an individual patient basis whenever necessary. In children, contrast medium dosing should be scaled to body weight. Injection rate should be scaled similarly and preferably delivered via powered injection. 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 at a maximum increment of 50% of the effective section thickness. The acquisition should at least cover the aortic arch, the origin and cervical course of the subclavian and carotid arteries, the Circle of Willis, and up to the vertex. In some patients, coverage can extend to include the complete aortic arch, the left atrium, the distal intracranial arteries, and the venous sinuses. In the pediatric population, anatomic coverage should be strictly limited to the vascular segments of interest, in order to keep the radiation dose as low as possible.

Postprocessing of the CTA by either physicians or licensed radiology technologists or appropriately trained staff to provide multiplanar reformations and/or 3D renderings is recommended [39]. 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 digitally on the workstations.

When applying the North American Symptomatic Carotid Endarterectomy Trial (NASCET) method, 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 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 equivalent data. When faced with near occlusion, the NASCET methodology does not apply [34,38,40-46].

#### D. Interpretation

Cervicocerebral CTAs are preferentially interpreted on a workstation that allows stacked cine paging of the primary transverse and the reformatted CTA sections. A complete interpretation includes review of the transverse CT sections and, in selected cases, 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. 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 dissection, stenosis, and aneurysmal dilatation. The visible portion of the brain, spine, facial sinuses, airways, esophagus, thyroid and salivary glands, and lymph node regions should be commented on when appropriate. Particular attention should be paid to the lung apices to detect any nodules.

## VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

In addition to examining the cervicocerebral vascular structures of interest, the CTA sections should be examined for extravascular abnormalities that may have clinical relevance. These abnormalities should be described in the formal report of the examination.

## VII. EQUIPMENT SPECIFICATIONS

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

1. Cervicocerebral CTA should be performed on a MDCT scanner, preferably with greater than or equal to 4 active detector rows.
2. Gantry rotation: 1 second or less for cervicocerebral CTA.
3. Tube heat capacity that allows for a single  $\geq 10$  second acquisitions.
4. Minimum section thickness: no greater than 3 mm, preferably 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.

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.

#### VIII. 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 is the concept “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)

#### IX. 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>).

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

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