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## **ACR–NASCI–SIR–SPR PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF BODY 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), the North American Society of Cardiovascular Imagers (NASCI), the Society for Pediatric Radiology (SPR), and the Society of Interventional Radiology (SIR).

### **II. DEFINITION**

Body computed tomography angiography (CTA) is a method for characterizing vascular anatomy, diagnosing vascular diseases, planning treatment for vascular diseases, and assessing the effectiveness of vascular treatment. Following intravenous injection of iodinated contrast medium, CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3D renderings [1].

### **III. INDICATIONS**

Indications for Body CTA include, but are not limited to:

1. Aneurysmal disease: Diagnosis, localization, characterization, and pretreatment planning of vascular aneurysms.
2. Dissection and dissection variants: Diagnose presence, location, and extent of vascular dissection and intramural hematoma, and determine appropriate treatment.
3. Arterial occlusive disease: Diagnose, localize, and characterize disease entities, including but not limited to aortoiliac stenoses and occlusion, upper and lower extremity peripheral arterial disease, Renovascular disease, mesenteric ischemia and vasculitis, also pretreatment planning.
4. Trauma: Assess for presence and location of vascular, solid organ, and visceral organ injury and hemorrhage, and determine appropriate management option [2-3].
5. Thromboembolic disease: Diagnose presence and extent of arterial and venous thrombi and thromboembolic. Guide endovascular treatment of thromboembolic and atheroembolic disease.
6. Oncology: Determine vascular anatomy of tumors, for prognostic and endovascular, surgical treatment planning and determine treatment response [4-5].
7. Vascular malformations: Localize, characterize for the purpose of diagnosis and possible treatment planning.
8. Anatomic Mapping: Characterization of normal and variant vascular anatomy for planning organ transplantation [6], planning autografts for musculoskeletal and breast reconstruction [7], or treatment of uretero-pelvic junction obstruction [8], popliteal entrapment syndrome, and thoracic outlet syndrome.
9. Localize and characterize blood supply to congenital abnormalities for purpose of diagnosis and treatment planning.
10. Diagnose and localize diseases with primary manifestations in the arterial wall, including vasculitides, infection, and degenerative disorders.
11. Assess the effectiveness of arterial and venous reconstruction or bypass using both traditional surgery and transluminal therapy. Determine the patency, location, and/or integrity of grafts and other vascular devices, including but not limited to grafts, stent-grafts, stents, vena caval filters, and radio-opaque embolic material.

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 \(CT\)](#).

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](#).
2. The physician is responsible for reviewing indications for the examination and for specifying the parameters of image acquisition; the route, volume, concentration, timing, type, and rate of contrast injection; and the method of image reconstruction, rendering, and storage. The physician should monitor the quality of the images and interpret the study. Interpreting physicians must be knowledgeable of the anatomy and diseases of the cardiovascular system and their treatment.
3. Nonradiologist physicians meeting the aforementioned criteria additionally must be able to identify important nonvascular abnormalities that may be present on CT angiograms. The abnormalities include neoplasia, sequel of infection, visceral and musculoskeletal 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 measurement of vessel dimensions.

#### **V. SPECIFICATIONS OF THE EXAMINATION**

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

For performing CTA of the chest, preliminary laboratory test results that raise the pretest probability of finding a pulmonary embolus (in particular, the presence of elevated D-dimer levels) should be available to the performing radiologist prior to the examination. When chest CTA for pulmonary embolism is performed, for reasons of limiting radiation dose, performance of a delayed "runoff" study of the venous system of the pelvis and lower extremities should be justified.

#### A. Patient Selection and Preparation

A brief history focused on identifying potential contraindications to the intravenous administration of iodinated contrast should be obtained from each patient prior to the examination. If an absolute contraindication is present, CTA should not be performed, and an alternative vascular imaging modality should be considered. If a relative contraindication to iodinated contrast media such as renal insufficiency or a previous allergic reaction is identified, the patient should be prepared following the [ACR–SPR Practice Guideline for the Use of Intravascular Contrast Media](#) and the [ACR Manual on Contrast Media](#).

Once a patient is determined to be a candidate for CTA, additional steps to maximize the quality of the examination while minimizing any adverse effect on the patient should be taken. The patient should be well hydrated both before and after the examination. The patient should not receive any positive bowel contrast agents, although use of a negative contrast agent could be considered.

If a central venous catheter approved for power injection is not already present, intravenous access should be established with placement of an appropriately sized catheter (typically 20-gauge or larger in an adult) in a vein in the antecubital fossa or forearm. The catheter should be tested with a rapid bolus injection of sterile saline to insure that the venous access is secure and can accommodate power injection.

#### B. CT Equipment

The use of a multidetector-row CT (MDCT) scanner is preferred for CTA [9]. Helical, wide area-detector cine, or prospectively ECG triggered CT acquisition are used 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. For cardiac and some ascending aortic CTA, an ECG-gated acquisition should be performed that allows retrospective reconstruction of the scan volume at multiple phases through the cardiac cycle.

A powered contrast medium injector that allows programming of both the volume and flow rate should be used for CTA examinations, except in some young pediatric patients in whom manual administration may be acceptable.

A workstation capable of creating multiplanar reformations, maximum-intensity projections, and volume renderings should be available for complete review of the imaging study. The workstation should also allow the direct measurement of vascular diameters and, when appropriate, path lengths and angles.

#### C. CTA Technique

Prior to acquiring the CT angiogram, 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. Unenhanced CT acquisitions are usually not needed in pediatric patients particularly given the radiation exposure associated with this additional CT scanning. The section thickness for this preliminary CT acquisition is application dependent. Ideally it should be the same thickness as the CTA but should not exceed 5 mm. The radiation exposure to the patient should be minimized within the limits of acceptable image quality. Acceptable radiation exposure should consider the size and age of the patient to apply the principle of using a radiation dose that is as low as reasonably achievable (ALARA). This radiation exposure should be characterized and minimized by lowering the kVp value in appropriately sized patients to 80 kVp or 100 kVp and apply in longitudinal and possibly also transverse mA dose adjustment, using noise settings that are optimized for the clinical indication of the study, according to published literature on this subject [10]. Achieving an appropriate radiation dose is a particularly important consideration in pediatric patients and young adults, who are more susceptible than older patients to the potentially harmful effects of ionizing radiation [11-14].

The CTA acquisition should be performed with a nominal section thickness of 3 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 to enhance the quality of 2D and 3D reconstruction images and to prevent artifacts [15-17]. The exception is when a very thin collimation (0.5 mm to 1.0 mm) is used with a higher number (>4) of MDCT, which results in an isotropic data set where spatial resolution is the same regardless of the plane of reformation [18].

A delayed phase acquisition may be indicated in some settings and is usually performed with a maximum section thickness of 3 mm. These settings include, but are not limited to, the detection of endoleaks following arterial stent grafting [19], mapping of venous anatomy following arterial assessment, and ureteral and renal collecting system mapping.

#### D. Contrast Medium Delivery

Nonionic contrast medium, preferably at least 350 mgI/ml, should be used for CTA. The dosage of iodine should be selected in consideration of the patient's weight and comorbidities that might increase the risk of nephrotoxicity [20]. The administration of contrast media for the CT angiogram should ideally be performed with a minimum flow rate of 3 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. For all patients, but particularly for children, contrast medium dosing should be scaled to body weight. While all CTA in adults and large children should be performed with a power injector, for infants and young children with small intravenous catheters (e.g., 24 gauge) or central venous catheters [21], the use of a power injector is optional, but preferred, as the complication rates have been low [22-23]. In these pediatric patients, the contrast medium can be successfully administered manually at a rate of 0.5 ml to 1.5 ml per second [23].

When performing thoracic CTA, a right-arm injection is preferable to a left-arm injection to avoid artifacts from undiluted contrast medium in the left brachiocephalic vein. In infants without available antecubital veins for intravenous catheter placement, scalp vein or lower extremity peripheral vein can be used for intravenous contrast administration. When possible, a bolus of saline following the iodinated contrast medium injection may be used to reduce the volume of contrast medium required to achieve adequate vascular opacification.

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 three techniques:

1. Intravenous injection of a small bolus (e.g., 10 ml to 15 ml) of contrast medium at the rate and through the access that will be used for the CT angiogram followed by acquisition of sequential stationary 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 attenuation curve. The peak of the curve is used to determine the scanning delay.
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 CT angiogram is automatically started when the enhancement in the vessel reaches a predetermined operator selected level. This method may be challenging in infants and young children with small vessels.
3. While bolus tracking or administration of a timing bolus is recommended for CTA in general, in infants and young pediatric patients, because of limitations in total contrast volume to be administered and to save radiation dose, empiric determination of the scan delay may be used. In these circumstances consideration of variations in circulation time to target vasculature for study should inform the delay time. Care should be taken that all of the calculated contrast volume is injected before the start of the scan by adjusting the injection rate to the highest possible, given the caliber of the available IV access and/or by reducing the total contrast volume accordingly, to accomplish this goal. Injection of a "chasing" bolus with saline to reduce streak artifacts from dense venous opacification is also encouraged whenever possible.

In patients with complex congenital heart disease involving cavopulmonary (Glenn) and/or Fontan anastomoses, the study should be set up so as to optimize the enhancement of the pulmonary vasculature. This may involve preferentially injecting the contrast volume in a lower extremity vein, and/or splitting the bolus for combined upper-extremity and lower-extremity injection, preferentially with two separate power injectors. Diagnostic quality contrast enhancement of pulmonary vasculature in these patients can be achieved by

optimizing three CT technical factors during CTA studies: 1) using simultaneous injections of contrast medium via catheters placed in both upper-extremity and lower-extremity veins; 2) performing a delayed second-phase CT scan in patients with bilateral Glenn shunt and markedly sluggish blood in the Fontan pathway or pulmonary artery, if there is suboptimal opacification on the first-phase CT scan; and 3) using a monitoring scan with bolus tracking to initiate CT scanning when optimal contrast enhancement is observed within the Fontan pathway and pulmonary vasculature [24].

#### E. Image Review and Post-Processing

CT angiograms should be interpreted on a workstation that allows stacked cine paging of the source and reformatted images. Interpretation of a CT angiogram includes review of the transverse sections, multiplanar/curved reformations, volume renderings, and any other images produced during postprocessing. On occasion, the physician reading the study will create postprocessed images to document important findings that are essential for accurate interpretation of the study. These images should be archived with the patient's original study and any other postprocessed images. Pertinent measurements of vascular dimensions should be performed digitally on the workstation. Complete interpretation of a CT angiogram includes evaluation of all other structures in the field of view at appropriate window levels in order to identify any nonvascular pathology that may be present.

Postprocessing of the CT angiogram by either physicians or radiology technologists to provide multiplanar reformations and/or 3D renderings is mandatory. Technologists processing 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. Volume renderings, maximum-intensity projections, and curved planar reformations must be created by a person knowledgeable of both cardiovascular 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, but must be performed with care to avoid excluding key regions of the anatomy or creating pseudolesions.

Images should be clearly labeled to indicate left and right. Manual labeling that identifies the artery and its situs is required when lateral or sagittal views of one of the iliac, upper-extremity, or lower-extremity arteries are displayed or when aortic branches are presented in isolation, typically using curved planar reformations. Postprocessed images should be recorded and archived in a manner similar to the source CT reconstructions.

#### F. Image Quality

As discussed previously, the CTA examination involves a combination of selecting the right patient for the right examination and then performing it on the appropriate scanner using the correct scanning protocol. All of the preceding requirements and recommendations are designed so that the examination performed has the image quality necessary for correct interpretation of the study in order to optimize patient care. Image quality can be defined in many ways, but in this era of optimizing dose protocols it is focused on the quality necessary to provide the information for which the study is ordered, yet doing so at the lowest dose possible (ALARA principle). It is a delicate balance between dose and optimizing the image quality. This balance is often not simple, especially when dealing with patients in the pediatric age group. However, even in adults, understanding appropriate image quality is challenging.

The definition and description of adequate image quality is difficult and will vary between different radiologists, even when they are looking at the same dataset. In consideration of the topic of CTA, several points are worth emphasizing:

1. Study quality requires at a minimum the opacification of the vessel in question between 250 to 300 Hounsfield units above baseline based on the published literature in order to optimize detection of vessel pathology. This requires the selection of the correct study protocol, which will include contrast injection volume, injection rate (cc/sec), and the timing of the injection. Whether preset timing delays, bolus tracking, or test bolus techniques are used, one needs to be certain of acquiring datasets in the appropriate time points (i.e. arterial vs. venous phase imaging). The complexity of the study be it CTA of the abdominal aorta vs. CTA of the pancreas vs. cardiac CTA will help determine what the optimal technique for contrast injection protocol and data acquisition timing [25-29].
2. Although 64 slice MDCT (and beyond) is ideal for CTA, 16 slice MDCT may be satisfactory for select applications. Regardless of which scanner is used, the protocols must be designed for that scanner specifically if optimal image quality is to be obtained. Specific scanning protocols including injection rates, scan delays, and contrast volume, may depend on the scanner system used.
3. The CT technologist must be trained specifically in acquiring CTA studies if optimal image quality is to be obtained. One cannot overemphasize the basics ranging from correct placement of adequate IV access to monitoring the safety of the IV access during delivery of the contrast bolus. Catheter size and placement may

need to be modified in pediatric patients. Image quality depends on a motion free study so the CT technologist must be trained in providing the correct breathing instructions to the patient as well as dealing with the patient in all aspects of the examination

4. The selection of scan protocols optimized for the scanner significantly impacts the image quality provided by the study. The use of smallest detector width, thin slice thickness, and appropriate overlap of reconstruction sections are critical parameters eventually helping to define image quality. Selection of the parameters chosen for specific applications will vary in part on the scanner used (16 slice MDCT vs. 64 slice MDCT vs. dual-source CT), whether or not multiplanar (MPR) or 3D processing is performed, the area scanned, the vessels to be evaluated (e.g., abdominal aorta vs. superior mesenteric artery [SMA] vs. inferior mesenteric artery [IMA]), and the age and size of the patient.

Image quality can be defined in terms of the source images (axial images) or the eventual postprocessed images. The image quality must be satisfactory for both with the post-processed images being in many ways the more demanding of the two. While individual axial images might look satisfactory once MPR or 3D imaging is performed, issues such as breathing between scan slices or a less than optimal breath hold can be very problematic. For patients capable of maintaining a breath hold, a breath hold consistent with the length of the study is critical if an optimal dataset is to be obtained.

Image quality becomes a topic of discussion and of critical importance regardless of whether one is looking at the source axial images or multiplanar reconstructions or three-dimensional images. Some of the components that are critical for optimal image quality include:

1. Selection of the appropriate scan parameters, especially of the section thickness and the interscan spacing. Thin sections (1 mm or less) with reconstruction at 50% overlap are often ideal for most applications. The smaller the vessels that need to be evaluated the smaller the slice thickness needs to be, especially if accurate measurement of the presence and degree of stenosis is required. With wider sections the issues of partial averaging become more critical.
2. Optimization of delivery of iodinated contrast and data acquisition is necessary for optimal study performance. Although most studies use arterial phase acquisitions for CTA, other studies may require both arterial and venous phase acquisitions (e.g., staging of pancreatic cancer), and others may require just venous phase acquisition (e.g., evaluate IVC or SVC patency). Regardless, the proper timing is critical for optimal image quality in order for proper study

interpretation. Acquisition of data either too early or too late relative to the phase necessary can result in errors in interpretation (both false positive and false negative studies) or even make the study impossible to interpret (e.g., poor opacification in a pulmonary CTA may make it impossible to diagnose a pulmonary embolism)

3. Appropriate volumes of iodinated contrast must be used for the clinical application selected. For example, a cardiac CTA may use 60 ml to 80 ml of iodinated contrast, while an aortic study with run-off may require in the range of 120 ml to 150 ml of contrast. Delivery rates of contrast will depend on the application as well as the scanner available for the study. Optimal image quality requires selection of the appropriate scan parameters for a specific scanner as discussed above.

After a quality dataset is acquired, the postprocessing of that dataset becomes the critical component of the study. Different models exist as to who actually creates the MPR/3D images ranging from the interpreting radiologist to the CT technologist to a dedicated 3D imaging laboratory where images are generated by either radiologists or well trained “3D technologists.” Regardless of the model followed, it is important that whoever generates the images is experienced in the use of the appropriate software and that quality assurance measures be used to make certain that processing is performed correctly. Correlation with surgical findings or with information from other studies often is ideal to maintain quality assurance by obtaining appropriate feedback mechanisms of study accuracy.

A detailed discussion of the postprocessing phase is beyond the scope of this section. Some helpful rules include:

1. The quality and capability of various software packages will vary from vendor to vendor. It is important that the appropriate software for the clinical applications used is available. Newer software packages provide important capabilities such as automated bone removal, improved centerline for vessel tracking and computer assisted measurement of the degree of stenosis present. When automated processing that results in segmentation of vessel margins is performed, there should be careful scrutiny of the segmentation accuracy, and manual adjustments should be considered.
2. The radiologist or technologist should be well trained on using the software. Training can be provided by the software vendor or colleagues with more experience using the software
3. The radiologist or technologist must be aware of the advantages of the various rendering techniques used, be it curved planar reconstruction, volume rendering or maximum

intensity projection. Potential pitfalls of each technique must also be understood.

4. Image capture with appropriate measurements must be provided as needed for each study. Because situs may be ambiguous on processed images, all images must be carefully labeled to indicate the vessel being displayed. Processed images should be sent to the picture archiving and communication system (PACS) and included in the original study. Delivery of appropriate images to the referring or consulting clinician may also be accomplished by email, web servers, or even printed film delivered in a way that complies with the Health Insurance Portability and Accountability Act (HIPAA). Regardless of how the information is delivered, it must be done in a timely manner.

Optimization of image quality is a complex process that requires many steps for each patient. Only a concerted effort of the referring clinician, the radiologist and the radiologic technologist can meet the goals listed above.

#### G. Special Applications

Special applications include modifying scanning techniques, increasing the number of sequences required, imaging with physiologic maneuvers, or modifying contrast administration protocol. It is not possible to address all applications here, but general principles can be outlined.

Imaging with various physiologic maneuvers may elucidate non-atherosclerotic vascular stenosis as a result of compression by adjacent anatomic structures. For example, evidence of popliteal entrapment syndrome may be more apparent during forced plantar flexion; evidence of thoracic outlet syndrome may be more apparent with abduction and external rotation of the affected arm; and evidence of median arcuate ligament syndrome may be more apparent during expiration. Imaging with and without the physiologic maneuver may be accomplished using a split contrast bolus technique, or by obtaining serial scans after administration of a single contrast bolus. If a single bolus technique is used, the initial, arterial phase scan can be performed with the physiologic maneuver, or in the position in which the patient experiences symptoms, followed by delayed acquisition in the neutral position, to enhance visualization of arterial compression. For imaging of the upper extremity, as in suspected thoracic outlet syndrome, the IV catheter should be placed in the uninvolved extremity to avoid dense opacification of adjacent venous structures during arterial phase imaging.

Precontrast images in a CTA examination need to be obtained occasionally, e.g., to identify calcifications in a pathological process, such as a neoplasm. In such cases, it

is important to confine the additional images to the area of concern.

CTA includes imaging of both arterial and venous structures, although the techniques differ for each of these vascular systems. CT venography may be performed using indirect, direct, or hybrid technique. Indirect CT venography is accomplished by imaging in the delayed phase after contrast medium administration, such that the contrast has circulated through the arterial system and then fills the venous system. The precise delay between initiation of the contrast bolus and scanning will depend upon the specific venous anatomy being imaged and the rate of contrast administration. Direct venography is performed during injection of dilute contrast through an IV placed distally in the extremity of interest. Imaging of both extremities and central veins would require simultaneous bilateral injections, and therefore a hybrid technique may be more practical in these cases, such as in evaluating superior vena cava syndrome or planning for dialysis access. In this example, an initial bolus of full strength contrast medium is followed by imaging during delayed injection of dilute contrast, thus producing direct venography of the arm with the IV catheter and indirect venography of the contralateral arm and chest.

A similarly divided contrast injection technique may be used in cases in which both arterial and venous information is desired, such as in hepatic or renal angiography. This may halve the radiation dose without loss of information by avoiding separate arterial phase and venous phase scans [30]. Approximately 60% of the contrast dose may be injected with scan delay appropriate for venous scanning, and the remaining 40% of the contrast can be given as a second dose, with a time interval prior to scan coincident with the arterial delay. In this manner, both arterial and venous information can be obtained with a single scan.

## VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#). All vessel diameter measurements reported should be made perpendicular to the median vessel centerline using MPR. Diameter should not be reported from measurements made directly from CT source images transverse to the patient.

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

## VII. EQUIPMENT SPECIFICATIONS

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 size 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 concept is known as “as low as reasonably achievable (ALARA).”

Facilities, in consultation with the medical physicist, should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active; if not, manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. Periodically, radiation exposures should be measured and patient radiation doses estimated by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006 – revised in 2009, Resolution 11)

## IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality (including standards for imaging protocol review), patient and imaging specialist 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 site (<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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Collaborative Committee – members represent their societies in the initial and final revision of this guideline

### ACR

Geoffrey D. Rubin, MD, Chair  
James A. Brink, MD, FACR  
Marta Hernanz-Schulman, MD, FACR

### NASCI

Elliot K. Fishman, MD, FACR  
Harold I. Litt, MD, PhD  
Pamela K. Woodard, MD, FACR

### SIR

Sanjoy Kundu, MD  
LeAnn S. Stokes, MD

### SIR

Michael J. Callahan, MD  
Francis P. Chan, MD, PhD  
Donald P. Frush, MD, FACR  
Edward Y. Lee, MD, MPH  
Sjirk Jan Westra, MD

Committee on Cardiac Imaging – ACR Committee responsible for sponsoring the draft through the process

Geoffrey D. Rubin, MD, Chair  
David A. Bluemke, MD, PhD, FACR  
Karin E. Dill, MD  
Andre J. Duerinckx, MD, PhD, FACR  
Scott D. Flamm, MD  
Thomas M. Grist, MD, FACR  
Jill E. Jacobs, MD  
Michael T. Lavelle, MD  
U. Joseph Schoepf, MD, FAHA  
Arthur E. Stillman, MD, PhD, FACR  
Pamela K. Woodard, MD, FACR  
James A. Brink, MD, FACR, Chair, Body Imaging Commission

Guidelines and Standards Committee – Pediatric – ACR Committee responsible for sponsoring the draft through the process

Marta Hernanz-Schulman, MD, FACR, Chair  
Sara J. Abramson, MD, FACR



Taylor Chung, MD  
 Brian D. Coley, MD  
 Kristin L. Crisci, MD  
 Wendy Ellis, MD  
 Eric N. Faerber, MD, FACR  
 Kate A. Feinstein, MD, FACR  
 Lynn A. Fordham, MD  
 S. Bruce Greenberg, MD  
 J. Herman Kan, MD  
 Beverley Newman, MB, BCh, BSc, FACR  
 Marguerite T. Parisi, MD  
 Sudha P. Singh, MB, BS  
 Donald P. Frush, MD, FACR, Chair, Pediatric  
 Commission

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\*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

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