Revised 2015 (Resolution 10)*

ACR–ASNR–SNIS–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF CERVICOCEREBRAL MAGNETIC RESONANCE ANGIOGRAPHY (MRA)

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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document 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 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

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, ___ N.W.2d ___ (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.

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 this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), the Society of NeuroInterventional Surgery (SNIS), and the Society for Pediatric Radiology (SPR).

Cervicocerebral magnetic resonance angiography (MRA) is a general term that refers to various MRA techniques used for the evaluation, assessment of severity, and follow-up of arterial and venous diseases of the cervicocerebral system. MRA is a rapidly evolving technology and, consequently, only general recommendations can be made regarding imaging techniques. Detailed imaging protocols have been omitted here to avoid promoting obsolete methodology. The practitioner should periodically review imaging protocols and update the protocols as needed using resources from the literature, major MR manufacturers and professional imaging society meetings and their websites (eg, American Society of Neuroradiology, International Society for Magnetic Resonance in Medicine, Society of Cardiovascular Magnetic Resonance, MR Angiography Club, and other similar resources).

Cervicocerebral MRA should be performed only for valid medical reasons. Additional or specialized pulse sequences are frequently required to optimize the examination. Although it is not possible to detect all abnormalities by using cervicocerebral MRA, adherence to the following practice parameter will enhance the probability of their detection.

MRA has important attributes that make it valuable in assessing a wide spectrum of vascular diseases [1,2]. Compared to radiographic catheter-based angiography, it is noninvasive with no risk of neurologic deficit, circulatory compromise due to vascular injury, or adverse effects of iodinated contrast material. Compared to vascular ultrasound, it is less operator-dependent, has greater freedom from interference by body habitus, and has greater 3-D capability. These benefits must be balanced against the limitations of MRA, which include artifacts generated by vascular flow, patient motion, and metal, which can lead to degraded imaging. The potential for nephrogenic systemic fibrosis (NSF) in at risk populations undergoing gadolinium contrast-enhanced (CE) MRA also needs to be considered [3-9]. The ACR Manual on Contrast Media provides detailed recommendations for the use of gadolinium contrast agents in at risk groups [10].

Children typically demonstrate a different spectrum of vascular conditions. Imaging protocols tailored for adult patients may not be optimal or even appropriate in the pediatric setting. Cervicocerebral MRA can provide valuable information regarding flow conditions, congenital/developmental vascular abnormalities, and acquired pathologic processes that may involve the pediatric brain and spine without the concern for radiation to the developing central nervous system. Performing successful MRA evaluation in pediatric patients is more complex and poses unique technical and safety issues [11]. In general, the fast intracranial flow in pediatric patients makes time-of-flight (TOF) MRA sequences a useful choice in most cases, reducing the need for the more technically challenging CE MRA. The smaller size of the pediatric patient requires higher resolution sequences. Finally, sedation is frequently necessary in order to obtain a diagnostic quality examination.

Application of this practice parameter should be in accordance with the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [12] and the ACR–SIR Practice Parameter for Sedation/Analgesia [13].

II. INDICATIONS

A. Pediatric Indications for Cervicocerebral MRA

MRI/MRA is typically the imaging modality of choice for the initial evaluation of the cervicocerebral vasculature in children [14]. It is a noninvasive and low-risk examination free of ionizing radiation, as compared to conventional endovascular or CT angiographic procedures. Studies of pediatric stroke that compared MRA to conventional angiography found MRA to be accurate in delineating stenosis and/or occlusion and able to demonstrate vascular anatomy in a variety of pathological conditions [15-22]. In some clinical instances, follow-up computed tomographic angiography (CTA) or catheter angiography may be necessary to fully characterize the abnormality.

Indications for cervicocerebral MRA in the pediatric population include, but are not limited to, the definition and evaluation of the following:

1. Evaluation of etiology of intracranial hemorrhage and intraspinal hemorrhage
2. Sickle cell vasculopathy [23]
3. Vasculitis and collagen vascular disease [24,25]
4. Moyamoya disease [26]
5. Detection and evaluation of aneurysms or pseudoaneurysms and venous varices [27,28]
6. Cerebral arteriovenous malformations (AVMs), arteriovenous fistulas, and venous and vascular malformations [29,30]
7. Vascular status following extracorporeal membrane oxygenation.
8. Blood supply to vascular neoplasms for operative planning
9. Acute ischemic stroke, vasospasm, and thromboembolism [31]
10. Traumatic injury to cervicocerebral vessels, including dissection [32]
11. Localization of arterial and venous structures for operative planning
12. Invasion, encasement, and constriction of blood vessels by neoplasm
13. Soft-tissue vascular anomalies in the head and neck region[33]
14. Dural sinus thrombosis and intracranial venous occlusive disease
15. Atherosclerotic steno-occlusive disease
16. Nonatherosclerotic, noninflammatory vasculopathy

B. Indications for cervicocerebral MRA for adults include, but are not limited to, the definition and evaluation of the following:

1. Presence and extent of atherosclerotic occlusive disease and thromboembolic phenomena in the setting of patients presenting with symptoms of cerebral ischemia and infarction [34-36]
2. Etiology of intracranial hemorrhage and intraspinal hemorrhage [37]
3. Relevant vascular anatomy for preprocedural evaluation and determining the effect of therapeutic measures, including the endovascular coil embolization treatment of aneurysms and AVM embolization [38,39]
4. Presence, location, and anatomy of extracranial and intracranial aneurysms and vascular malformations [40-42]
5. Presence, nature, and extent of traumatic injury to cervicocerebral vessels, including dissection [43,44]
6. Vascular supply to tumors and vessel encasement and narrowing by tumors
7. Dural sinus thrombosis and intracranial venous occlusive disease [45-47]
8. Nature and extent of other congenital or acquired AVM (soft tissue) vascular anomalies (eg, hemangioma, venous malformation, AVM, lymphatic malformation) [45-47]
9. Extent of disease in vasculitis and vasculopathy

10. Operative planning for tumor resection

C. Evaluation of the aortic arch and subclavian arteries in adults and children may require separate techniques and sequences. Indications include, but are not limited to, the following [48-50]:

1. Dissection of the aorta and great vessels to the brain
2. Aneurysm of the aorta and/or its branches
3. Presence and extent of atherosclerotic occlusive disease and subclavian steal
4. Differentiation of aneurysms and masses
5. Definition of the relationship of masses to nearby vascular structures
6. Identification of congenital abnormalities of the aorta, such as coarctation, double arch, and aberrant subclavian artery
7. Evaluation of superior vena cava syndrome or unilateral upper extremity edema
8. As a measuring tool for treatment of occlusive disease of the extracranial vessels (ie, subclavian, innominate, common carotid)

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [12].

IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [12] and the ACR Guidance Document on MR Safe Practices: 2013 [51].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [1,21].

V. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, benefits, and risks of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including incompatible devices and potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone (See the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [52].). The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The written or electronic request for MRA 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)

The supervising physician must also understand the pulse sequences to be used and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be

established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

A. Patient Selection

The physician responsible for the examination should supervise patient selection and preparation and be available in person or by phone for consultation. Patients must be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment (eg, incompatible metallic implants surgical devices, etc). See the ACR MR Guidance Document on MR Safe Practices: 2013 [51].

Certain indications require administration of intravenous (IV) contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast used. Patients receiving gadolinium contrast agents should be evaluated for potential risk of NSF according to the recommendations in the chapter on NSF in the ACR Manual on Contrast Media [10].

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may enable achievement of a successful examination. If moderate sedation is necessary, refer to the ACR–SIR Practice Parameter for Sedation/Analgesia [13]. Additional considerations and equipment may be required in critically ill or intubated patients under general anesthesia.

B. Facility Requirements

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.

C. Examination Technique

Magnetic resonance angiography is a general term that refers to a diverse group of MR pulse sequences. Multiple methods can be used to generate signal from flowing blood and each method may be performed with a variety of coils, acquisitions and display techniques. Time of flight techniques rely on flow enhancement to generate images of blood flow within the vascular lumen. Flow images and quantitative measurements of flow velocity can be obtained using phase-contrast (PC) MRA techniques in which the image contrast is generated by velocity-induced phase shifts. Contrast enhanced MRA relies on enhancement of the blood signal by paramagnetic contrast agents and typically uses rapid, 3-D T1-weighted gradient-echo acquisitions. Contrast enhanced MRA can provide higher spatial resolution with the first-pass techniques or provide temporal resolution with time-resolved techniques [53-56]. Vascular images can also be generated by arterial spin labeling and blood can be directly imaged using methods such as inflow inversion recovery [57-59]. Individuals using MRA must understand the artifacts and limitations of each imaging technique. The most commonly used techniques are noncontrast TOF and CE 3-D and 4-D methods.

1. Noncontrast TOF MRA
   In two-dimensional (2-D) TOF MRA acquisitions, multiple thin slices are obtained and combined to form a 3D volume data set. Vascular structures are isolated from the surrounding tissue by projecting the pixels with maximum intensity into multiple views called maximum intensity projection (MIP) images. Three-dimensional TOF technique directly acquire a 3-D volume. Multiple 3-D volumes using short TE/TR sequences are typically obtained with overlapping edges to provide coverage of the region of interest. Focused assessment of the vascular structures from the 3-D volume set can also be displayed with MIP imaging [60-63].

MRA datasets can also be displayed as 2-D source images. The supervising physician should always review the source images in an effort to improve diagnostic accuracy. Review of the source images can reduce possible confusion of high signal material (eg, fat or thrombus) with flow signal, aid diagnosis by eliminating overlapping structures, and identify artifacts that can cause spurious increase or decrease in flow-related signal [64].

Rotating displays of 3-D MIP images allow separation of vessels that are superimposed on routine projections. The supervising physician should be familiar not only with MIP displays, but also with surface displays, volume displays, and multiplanar reformatting techniques including the limitations and strengths of each method. The type and frequency of artifacts will vary with the display technique; thus, the supervising physician must understand the potential errors with each display method [65].

2. Contrast-enhanced MRA

Contrast-enhanced 3-D MRA combines a fast T1-weighted gradient-echo acquisition with an intravenously administered paramagnetic contrast agent [66]. Such agents reduce the T1 relaxation time of blood and nearly eliminate the loss of signal related to saturation effects, thus leading to a more accurate assessment of vascular stenosis. Contrast-enhanced MRA has been evaluated for use in assessing the cervical carotid and vertebral arterial system, the intracranial arterial circulation, the dural venous sinuses, and the ascending and descending thoracic aorta. Contrast-enhanced MRA has been successful in demonstrating atherosclerotic occlusive disease of the aorta, aortic dissection, anomalies of the aortic arch, vascular malformations, and vascular involvement by tumor. It does not routinely require cardiac gating, which makes it a more widely applicable technique in patients with irregular cardiac rhythms. Furthermore, respiratory artifacts are reduced by breath-holding, and artifacts due to flow-related enhancement or in-plane dephasing encountered with vascular tortuosity are much reduced. These advantages make CE MRA extremely useful for imaging of the aortic arch, great vessels, and intracranial circulation.

Contrast enhanced cervicocerebral MRA is optimized when the center of k-space is sampled near the peak arterial concentration of the gadolinium chelate. Centric encoding is an example of a vascular imaging technique that improves capture of the arterial phase of the bolus and reduces venous contamination of the image. Many other CE MRA techniques have been developed in order to better evaluate vascular pathology [36,67-71].

A contrast medium injection rate of 2 to 4 mL/sec generates a bolus profile with a 5 second to 7 second arterial phase. This is desirable because most techniques require several seconds to sample the center of k-space. The contrast injection volume may vary based on the size and condition of the patient [69]. For example, very large patients or those with known poor cardiac output may require a timing bolus and a larger volume of contrast in order to offset the effects of contrast dilution in the blood pool. The use of a power injector facilitates control of the injection rate and helps to standardize the protocol. Following injection of the contrast material, the power injector can rapidly switch to inject the saline flush. The dose and injection rate of contrast material will need to be adjusted accordingly for pediatric patients who typically have a faster circulation time. The size and location of the IV also needs special consideration in young children.

Rapid intracranial circulation, typically on the order of 8 to 10 seconds, makes CE MRA of the cervicocerebral vascular system particularly challenging. Arch and carotid cervicocerebral MRA studies require very accurate timing of the acquisition in relation to the contrast medium injection. If the images are obtained too early, the arterial structures may not be visualized. Late acquisition will result in reduced arterial signal, venous opacification, and soft-tissue enhancement. Ideally, the center of k-space is scanned during the first pass of the bolus [72].

A limitation of CE MRA is that the extracellular gadolinium chelates are nonspecific MR contrast agents. Many normal and pathologic tissues will enhance. This makes repeat imaging more problematic. Subtraction techniques may help, but often there is incomplete subtraction of the background, and artifacts generated by misregistration of the datasets can occur. Increased signal intensity of the enhanced adjacent soft tissues can obscure vessels on the MIP images and may simulate flow-related signal or degrade vascular detail. Blood-pool contrast agents (eg, gadofosveset trisodium) are available and may be of utility in dynamic CE MRA studies.

Saturation (SAT) bands are less effective when the T1 of blood is significantly reduced. In CE MRA, a poorly timed contrast bolus can result in undesirable venous enhancement, which cannot be eliminated by the selective placement of SAT bands, and relevant arterial anatomy may be obscured. Similarly, arterial structures cannot be selectively eliminated by saturation techniques when contrast material is administered. The type and frequency of artifacts will vary with the technique; thus, the supervising physician must understand the potential limitations of each acquisition method [73-75].

3. Phase contrast (PC) MRA
   Phase contrast MRA techniques are based on the physical properties of moving spins. As protons move through a magnetic field, they acquire a phase shift directly proportional to their velocity. The magnitude of the phase shift can be measured, and an image of the flowing blood can be generated. Display of the vessels is similar to that obtained with the TOF technique, although direction of flow can also be indicated. Contrast enhancement may also be used to increase the signal obtained from blood. In some instances, it is necessary to gate the PC acquisition to the cardiac cycle. When the proper velocity encoding is selected, the image data can be used to measure flow velocity or flow volume. When phase contrast MRA is used in this manner, it is frequently called 4-D flow MRA [76-80].

4. Initial results from recently developed clinically feasible MRA techniques such as continuous and pseudocontinuous arterial spin labeling (ASL) and inflow inversion recovery have shown clinical utility [57-59].

5. Vessel wall imaging
   The previously described MRA techniques display images of the vessel lumen. Black-blood T1-weighted techniques are emerging that permit imaging of the cervical/intracranial arterial wall and may be of clinical value in the setting of subintimal and intramural dissections and atherosclerotic disease. For example, the detection of a thin fibrous cap, lipid/necrotic core, intraplaque hemorrhage, and neovascularity have been reported to be associated with a higher risk of ischemic events [81-86]. Detection and characterization of vessel wall enhancement can suggest the diagnosis of vasculitis, vasoconstriction, or symptomatic atherosclerotic disease [87].

6. MR angiography of the venous system, also called MR venography (MRV), can be performed using TOF, PC, and CE imaging techniques. Display protocols should be modified to focus on the venous structures as clinically indicated.

VI. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [52].

In addition to examining the vascular structures of interest, the MRA source images should be examined for extravascular abnormalities that may have clinical relevance. These abnormalities should be described in the formal report of the examination. When MRA techniques are used for determining carotid stenosis, the report

should reflect the methodology and reference the criteria for percent stenosis outlined in the NASCET or based on methods validated against NASCET measurement [88-91]. Also, the percent stenosis must be calculated using the distal cervical ICA (internal carotid artery) diameter, where the walls are parallel, for the denominator. Similar to CTA, MRA with attention to the acquisition parameters and postprocessing techniques can provide cross-sectional measurements of stenosis that correlate with properly performed NASCET estimates of percent stenosis obtained with catheter angiography [92]. In the setting of near occlusion, it may not be accurate to calculate percent stenosis ratios in the presence of poststenotic arterial diameter decrease. Some MRA techniques may not be amenable to quantitative measurements, in which case qualitative assessment of stenosis should be provided.

VII. EQUIPMENT SPECIFICATIONS

The MR equipment specifications and performance must meet all state and federal requirements. These requirements include, but are not limited to, specifications of maximum static magnetic field strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

A workstation capable of creating multiplanar reformations, MIP images, and 3-D volume renderings or shaded surface displays is required for MR angiograms. The workstation should also allow the direct measurement of vascular diameters and, when appropriate, path lengths and branch angles, either from source images or from reformatted images.

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (http://www.acr.org/guidelines).

Specific policies and procedures related to MRI safety should be in place with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with the MRI examination of the patient as well as to others in the immediate area. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [93-95].

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment [96].

ACKNOWLEDGEMENTS

This practice parameter was revised as described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (http://www.acr.org/guidelines) by the Committee on Practice Parameters – Neuroradiology of the ACR Commission on Neuroradiology, the Committee on Practice Parameters – Interventional and Cardiovascular Radiology of the ACR Commission on Interventional and Cardiovascular Radiology, and the Committee on Practice Parameters – Pediatric Radiology of the ACR Commission on Pediatric Radiology in collaboration with the ASNR, the SNIS, and the SPR.

Collaborative Committee
Members represent their societies in the initial and final revision of this practice parameter.

ACR
Patrick A. Turski, MD, FACR, Chair

ASNR
David M. Mirsky, MD

J. Kevin DeMarco, MD
Ashok Srinivasan, MD
Lawrence N. Tanenbaum, MD, FACR

Srinivasan Mukundan Jr., MD, PhD
Richard L. Robertson, MD
Rathan M. Subramaniam, MD, PhD, MPH

SPR
Timothy N. Booth, MD
Susan Palasis, MD
Aylin Tekes, MD

SNIS
Sameer A. Ansari, MD, PhD
Yasha Kadkhodayan, MD
Richard P. Klucznik, MD
Albert J. Yoo, MD

Committee on Practice Parameters – Neuroradiology
(ACR Committee responsible for sponsoring the draft through the process)

John E. Jordan, MD, MPP, FACR, Chair
Merita A. Bania, MD
Kristine A. Blackham, MD
Robert J. Feiwell, MD
Steven W. Hetts, MD
Ellen G. Hoeffner, MD
Thierry A.G.M. Huisman, MD
Stephen A. Kieffer, MD, FACR
David M. Mirsky, MD
Srinivasan Mukundan, Jr., MD, PhD
A. Orlando Ortiz, MD, MBA, FACR
Robert J. Rapoport, MD, FACR
Glenn H. Roberson, MD
Ashok Srinivasan, MD
Rathan M. Subramaniam, MD, PhD, MPH
Raymond K. Tu, MD, FACR
Max Wintermark, MD

Committee on Practice Parameters – Interventional and Cardiovascular Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Aradhana M. Venkatesan, MD, FSIR, Chair
Stephen Balter, PhD, FACR, FSIR
Drew M. Caplin, MD
Sean R. Dariushnia, MD
Lawrence T. Dauer, PhD
Jeremy L. Friese, MD, MBA
Joshua A. Hirsch, MD, FACR, FSIR
Minhajuddin S. Khaja, MD, MBA
Sanjeeva P. Kalva, MD, FSIR
Susan K. O'Horo, MD, FSIR
Stephen P. Reis, MD
Wael Saad, MD, FSIR
Beth A. Schueler, PhD, FACR
John D. Statler, MD
Timothy L. Swan, MD, FACR, FSIR
Raymond H. Thornton, MD, FSIR

Clayton Trimmer, DO, FACR
Joan C. Wojak, MD, FASR, FSIR

Committee on Practice Parameters – Pediatric Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Eric N. Faerber, MD, FACR, Chair
Richard M. Benator, MD, FACR
Lorna P. Browne, MB, BCh
Timothy J. Carmody, MD
Brian D. Coley, MD, FACR
Lee K. Collins, MD
Monica S. Epelman, MD
Lynn A. Fordham, MD, FACR
Kerri A. Highmore, MD
Tal Laor, MD
Marguerite T. Parisi, MD, MS
Sumit Pruthi, MBBS
Nancy K. Rollins, MD
Pallavi Sagar, MD

Carolyn C. Meltzer, MD, FACR, Chair, Commission on Neuroradiology
Anne C. Roberts, MD, FACR, FSIR, Chair, Commission on Interventional & Cardio Radiology
Marta Hernanz-Schulman, MD, FACR, Chair, Commission on Pediatric Radiology
Debra L. Monticciolo, MD, FACR, Chair, Commission on Quality and Safety
Jacqueline Anne Bello, MD, FACR, Vice-Chair, Commission on Quality and Safety
Julie K. Timins, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards
Matthew S. Pollack, MD, FACR, Vice Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee
Christopher G. Ullrich, MD, FACR, Chair
Frank J. Lexa, MD, MBA, Co-Chair
Sameer A. Ansari, MD, PhD
Kimberly E. Applegate, MD, MS, FACR
Timothy N. Booth, MD
J. Kevin DeMarco, MD
Kavita K. Erickson, MD
Eric N. Faerber, MD, FACR
Marta Hernanz-Schulman, MD, FACR
William T. Herrington, MD, FACR
John E. Jordan, MD, MPP, FACR
Yasha Kadkhodayan, MD
Richard P. Klucznik, MD
Carolyn C. Meltzer, MD, FACR
David M. Mirsky, MD
Debra L. Monticciolo, MD, FACR
Srinivasan Mukundan Jr., MD, PhD
Susan Palasis, MD
Matthew S. Pollack, MD, FACR
Robert J. Rapoport, MD, FACR
Anne C. Roberts, MD, FACR, FSIR
Richard L. Robertson, MD

Michael I. Rothman, MD
Ashok Srinivasan, MD
Rathan M. Subramaniam, MD, PhD, MPH
Lawrence N. Tanenbaum, MD, FACR
Aylin Tekes, MD
Julie K. Timins, MD, FACR
Patrick A. Turski, MD, FACR
Aradhana M. Venkatesan, MD, FSIR
Albert J. Yoo, MD

REFERENCES

1. Rosamond W, Flegal K, Friday G, et al. Heart disease and stroke statistics--2007 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation.* 2007;115(5):e69-171.
2. Carr JC, Carroll TJ. *Magnetic resonance angiography: principles and applications*. New York: Springer, Part of Springer Science + Business Media; 2012.
3. Agarwal R, Brunelli SM, Williams K, Mitchell MD, Feldman HI, Umscheid CA. Gadolinium-based contrast agents and nephrogenic systemic fibrosis: a systematic review and meta-analysis. *Nephrol Dial Transplant.* 2009;24(3):856-863.
4. Boyd AS, Zic JA, Abraham JL. Gadolinium deposition in nephrogenic fibrosing dermopathy. *J Am Acad Dermatol.* 2007;56(1):27-30.
5. Broome DR. Nephrogenic systemic fibrosis associated with gadolinium based contrast agents: a summary of the medical literature reporting. *Eur J Radiol.* 2008;66(2):230-234.
6. Bryant BJ, 2nd, Im K, Broome DR. Evaluation of the incidence of nephrogenic systemic fibrosis in patients with moderate renal insufficiency administered gadobenate dimeglumine for MRI. *Clin Radiol.* 2009;64(7):706-713.
7. Grobner T. Gadolinium--a specific trigger for the development of nephrogenic fibrosing dermopathy and nephrogenic systemic fibrosis? *Nephrol Dial Transplant.* 2006;21(4):1104-1108.
8. Sadowski EA, Bennett LK, Chan MR, et al. Nephrogenic systemic fibrosis: risk factors and incidence estimation. *Radiology.* 2007;243(1):148-157.
9. Schneider G, Schurholz H, Kirchin MA, Bucker A, Fries P. Safety and adverse effects during 24 hours after contrast-enhanced MRI with gadobenate dimeglumine (MultiHance) in children. *Pediatr Radiol.* 2013;43(2):202-211.
10. American College of Radiology. Manual on Contrast Media v9. 2013; Available at: http://www.acr.org/Quality-Safety/Resources/Contrast-Manual. Accessed April 14, 2014.
11. Huisman TA, Singhi S, Pinto PS. Non-invasive imaging of intracranial pediatric vascular lesions. *Childs Nerv Syst.* 2010;26(10):1275-1295.
12. American College of Radiology. ACR practice parameter for performing and interpreting magnetic resonance imaging (MRI). 2011; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Perf-Interpret.pdf. Accessed November 21, 2014.
13. American College of Radiology. ACR-SIR practice parameter for sedation/analgesia. 2010; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/FluoroConEnema.pdf. Accessed November 21, 2014.
14. Bowers KJ, Deveber GA, Ferriero DM, Roach ES, Vexler ZS, Maria BL. Cerebrovascular disease in children: recent advances in diagnosis and management. *J Child Neurol.* 2011;26(9):1074-1100.
15. Aviv RI, Benseler SM, Silverman ED, et al. MR imaging and angiography of primary CNS vasculitis of childhood. *AJNR Am J Neuroradiol.* 2006;27(1):192-199.

16. Chooi WK, Woodhouse N, Coley SC, Griffiths PD. Pediatric head and neck lesions: assessment of vascularity by MR digital subtraction angiography. *AJNR Am J Neuroradiol.* 2004;25(7):1251-1255.
17. Chung T, Krishnamurthy R. Contrast-enhanced MR angiography in infants and children. *Magn Reson Imaging Clin N Am.* 2005;13(1):161-170, vi-vii.
18. Husson B, Lasjaunias P. Radiological approach to disorders of arterial brain vessels associated with childhood arterial stroke-a comparison between MRA and contrast angiography. *Pediatr Radiol.* 2004;34(1):10-15.
19. Mukundan S, Fuchs H, Alexander MJ, Grant GA. Dynamic contrast-enhanced magnetic resonance angiography of vascular malformations in pediatric patients. Case report. *J Neurosurg.* 2007;107(3 Suppl):228-231.
20. Padayachee TS, Bingham JB, Graves MJ, Colchester AC, Cox TC. Dural sinus thrombosis. Diagnosis and follow-up by magnetic resonance angiography and imaging. *Neuroradiology.* 1991;33(2):165-167.
21. Wiznitzer M, Masaryk TJ. Cerebrovascular abnormalities in pediatric stroke: assessment using parenchymal and angiographic magnetic resonance imaging. *Ann Neurol.* 1991;29(6):585-589.
22. Wiznitzer M, Ruggieri PM, Masaryk TJ, Ross JS, Modic MT, Berman B. Diagnosis of cerebrovascular disease in sickle cell anemia by magnetic resonance angiography. *J Pediatr.* 1990;117(4):551-555.
23. Zimmerman RA. MRI/MRA evaluation of sickle cell disease of the brain. *Pediatr Radiol.* 2005;35(3):249-257.
24. Twilt M, Benseler SM. The spectrum of CNS vasculitis in children and adults. *Nat Rev Rheumatol.* 2012;8(2):97-107.
25. Aviv RI, Benseler SM, DeVeber G, et al. Angiography of primary central nervous system angiitis of childhood: conventional angiography versus magnetic resonance angiography at presentation. *AJNR Am J Neuroradiol.* 2007;28(1):9-15.
26. Houkin K, Nakayama N, Kuroda S, Nonaka T, Shonai T, Yoshimoto T. Novel magnetic resonance angiography stage grading for moyamoya disease. *Cerebrovasc Dis.* 2005;20(5):347-354.
27. Hetts SW, English JD, Dowd CF, Higashida RT, Scanlon JT, Halbach VV. Pediatric intracranial aneurysms: new and enlarging aneurysms after index aneurysm treatment or observation. *AJNR Am J Neuroradiol.* 2011;32(11):2017-2022.
28. Li MH, Li YD, Tan HQ, et al. Contrast-free MRA at 3.0 T for the detection of intracranial aneurysms. *Neurology.* 2011;77(7):667-676.
29. Roccatagliata L, Bracard S, Holmin S, Soderman M, Rodesch G. Pediatric intracranial arteriovenous shunts: a global overview. *Childs Nerv Syst.* 2013;29(6):907-919.
30. Taschner CA, Gieseke J, Le Thuc V, et al. Intracranial arteriovenous malformation: time-resolved contrast-enhanced MR angiography with combination of parallel imaging, keyhole acquisition, and k-space sampling techniques at 1.5 T. *Radiology.* 2008;246(3):871-879.
31. Steinlin M. A clinical approach to arterial ischemic childhood stroke: increasing knowledge over the last decade. *Neuropediatrics.* 2012;43(1):1-9.
32. Tolhurst SR, Vanderhave KL, Caird MS, et al. Cervical arterial injury after blunt trauma in children: characterization and advanced imaging. *J Pediatr Orthop.* 2013;33(1):37-42.
33. Kim JS, Chandler A, Borzykowski R, Thornhill B, Taragin BH. Maximizing time-resolved MRA for differentiation of hemangiomas, vascular malformations and vascularized tumors. *Pediatr Radiol.* 2012;42(7):775-784.
34. Debrey SM, Yu H, Lynch JK, et al. Diagnostic accuracy of magnetic resonance angiography for internal carotid artery disease: a systematic review and meta-analysis. *Stroke.* 2008;39(8):2237-2248.
35. JM UK-I, Trivedi R, Cross J, et al. Conventional digital subtraction x-ray angiography versus magnetic resonance angiography in the evaluation of carotid disease: patient satisfaction and preferences. *Clin Radiol.* 2004;59(4):358-363.
36. Willinek WA, von Falkenhausen M, Born M, et al. Noninvasive detection of steno-occlusive disease of the supra-aortic arteries with three-dimensional contrast-enhanced magnetic resonance angiography: a prospective, intra-individual comparative analysis with digital subtraction angiography. *Stroke.* 2005;36(1):38-43.

37. Cosottini M, Pingitore A, Puglioli M, et al. Contrast-enhanced three-dimensional magnetic resonance angiography of atherosclerotic internal carotid stenosis as the noninvasive imaging modality in revascularization decision making. *Stroke.* 2003;34(3):660-664.
38. Nussel F, Wegmuller H, Huber P. Comparison of magnetic resonance angiography, magnetic resonance imaging and conventional angiography in cerebral arteriovenous malformation. *Neuroradiology.* 1991;33(1):56-61.
39. Pollock BE, Gorman DA, Brown PD. Radiosurgery for arteriovenous malformations of the basal ganglia, thalamus, and brainstem. *J Neurosurg.* 2004;100(2):210-214.
40. Adams WM, Laitt RD, Jackson A. The role of MR angiography in the pretreatment assessment of intracranial aneurysms: a comparative study. *AJNR Am J Neuroradiol.* 2000;21(9):1618-1628.
41. Anzalone N, Scomazzoni F, Cirillo M, et al. Follow-up of coiled cerebral aneurysms at 3T: comparison of 3D time-of-flight MR angiography and contrast-enhanced MR angiography. *AJNR Am J Neuroradiol.* 2008;29(8):1530-1536.
42. Wallace RC, Karis JP, Partovi S, Fiorella D. Noninvasive imaging of treated cerebral aneurysms, part I: MR angiographic follow-up of coiled aneurysms. *AJNR Am J Neuroradiol.* 2007;28(6):1001-1008.
43. Levy C, Laissy JP, Raveau V, et al. Carotid and vertebral artery dissections: three-dimensional time-of-flight MR angiography and MR imaging versus conventional angiography. *Radiology.* 1994;190(1):97-103.
44. 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(9):1753-1760.
45. 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 S42-13.
46. Liang L, Korogi Y, Sugahara T, et al. Evaluation of the intracranial dural sinuses with a 3D contrast-enhanced MP-RAGE sequence: prospective comparison with 2D-TOF MR venography and digital subtraction angiography. *AJNR Am J Neuroradiol.* 2001;22(3):481-492.
47. Tsai FY, Wang AM, Matovich VB, et al. MR staging of acute dural sinus thrombosis: correlation with venous pressure measurements and implications for treatment and prognosis. *AJNR Am J Neuroradiol.* 1995;16(5):1021-1029.
48. Van Grimberge F, Dymarkowski S, Budts W, Bogaert J. Role of magnetic resonance in the diagnosis of subclavian steal syndrome. *J Magn Reson Imaging.* 2000;12(2):339-342.
49. Wutke R, Lang W, Fellner C, et al. High-resolution, contrast-enhanced magnetic resonance angiography with elliptical centric k-space ordering of supra-aortic arteries compared with selective X-ray angiography. *Stroke.* 2002;33(6):1522-1529.
50. Yang CW, Carr JC, Futterer SF, et al. Contrast-enhanced MR angiography of the carotid and vertebrobasilar circulations. *AJNR Am J Neuroradiol.* 2005;26(8):2095-2101.
51. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging.* 2013;37(3):501-530.
52. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings. 2014; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf. Accessed November 21, 2014.
53. Chandra T, Pukenas B, Mohan S, Melhem E. Contrast-enhanced magnetic resonance angiography. *Magn Reson Imaging Clin N Am.* 2012;20(4):687-698.
54. Honglei Z, Zhang W, Prince MR. *Technical aspect of contrast-enhanced magnetic resonance angiography*. New York: Springer; 2012; 65-73.
55. Schanker BD, Walcott BP, Nahed BV, et al. Time-resolved contrast-enhanced magnetic resonance angiography in the investigation of suspected intracranial dural arteriovenous fistula. *J Clin Neurosci.* 2011;18(6):837-839.

56. Schrauben EM, Johnson KM, Huston J, et al. Reproducibility of Cerebrospinal Venous Blood Flow and Vessel Anatomy with the Use of Phase Contrast-Vastly Undersampled Isotropic Projection Reconstruction and Contrast-Enhanced MRA. *AJNR Am J Neuroradiol.* 2014;35(5):999-1006.
57. Glockner JF, Takahashi N, Kawashima A, et al. Non-contrast renal artery MRA using an inflow inversion recovery steady state free precession technique (Inhance): comparison with 3D contrast-enhanced MRA. *J Magn Reson Imaging.* 2010;31(6):1411-1418.
58. Wu H, Block WF, Turski PA, Mistretta CA, Johnson KM. Noncontrast-enhanced three-dimensional (3D) intracranial MR angiography using pseudocontinuous arterial spin labeling and accelerated 3D radial acquisition. *Magn Reson Med.* 2013;69(3):708-715.
59. Wu H, Block WF, Turski PA, et al. Noncontrast dynamic 3D intracranial MR angiography using pseudo-continuous arterial spin labeling (PCASL) and accelerated 3D radial acquisition. *J Magn Reson Imaging.* 2014;39(5):1320-1326.
60. Babiarz LS, Romero JM, Murphy EK, et al. Contrast-enhanced MR angiography is not more accurate than unenhanced 2D time-of-flight MR angiography for determining > or = 70% internal carotid artery stenosis. *AJNR Am J Neuroradiol.* 2009;30(4):761-768.
61. Willinek WA, Born M, Simon B, et al. Time-of-flight MR angiography: comparison of 3.0-T imaging and 1.5-T imaging--initial experience. *Radiology.* 2003;229(3):913-920.
62. Edelman RR, Hesselink J. *Clinical Magnetic Resonance Imaging 3rd ed*. Philadelphia, Pa: WB Saunders Co; 2004.
63. Wallace RC, Karis JP, Partovi S, Fiorella D. Noninvasive imaging of treated cerebral aneurysms, Part II: CT angiographic follow-up of surgically clipped aneurysms. *AJNR Am J Neuroradiol.* 2007;28(7):1207-1212.
64. Nederkoorn PJ, Elgersma OE, Mali WP, Eikelboom BC, Kappelle LJ, van der Graaf Y. Overestimation of carotid artery stenosis with magnetic resonance angiography compared with digital subtraction angiography. *J Vasc Surg.* 2002;36(4):806-813.
65. Anderson CM, Saloner D, Tsuruda JS, Shapeero LG, Lee RE. Artifacts in maximum-intensity-projection display of MR angiograms. *AJR Am J Roentgenol.* 1990;154(3):623-629.
66. Prince MR, Grist TM, Debatin JF. *Contrast MR Angiography*. Berlin, Germany: Springer-Verlag; 2003.
67. Lim RP, Shapiro M, Wang EY, et al. 3D time-resolved MR angiography (MRA) of the carotid arteries with time-resolved imaging with stochastic trajectories: comparison with 3D contrast-enhanced Bolus-Chase MRA and 3D time-of-flight MRA. *AJNR Am J Neuroradiol.* 2008;29(10):1847-1854.
68. Lohan DG, Tomasian A, Saleh RS, Singhal A, Krishnam MS, Finn JP. Ultra-low-dose, time-resolved contrast-enhanced magnetic resonance angiography of the carotid arteries at 3.0 tesla. *Invest Radiol.* 2009;44(4):207-217.
69. Nael K, Moriarty JM, Finn JP. Low dose CE-MRA. *Eur J Radiol.* 2011;80(1):2-8.
70. Nael K, Ruehm SG, Michaely HJ, et al. High spatial-resolution CE-MRA of the carotid circulation with parallel imaging: comparison of image quality between 2 different acceleration factors at 3.0 Tesla. *Invest Radiol.* 2006;41(4):391-399.
71. Willinek WA, Hadizadeh DR, von Falkenhausen M, et al. 4D time-resolved MR angiography with keyhole (4D-TRAK): more than 60 times accelerated MRA using a combination of CENTRA, keyhole, and SENSE at 3.0T. *J Magn Reson Imaging.* 2008;27(6):1455-1460.
72. JM UK-I, Trivedi RA, Graves MJ, et al. Contrast-enhanced MR angiography for carotid disease: diagnostic and potential clinical impact. *Neurology.* 2004;62(8):1282-1290.
73. Nederkoorn PJ, Elgersma OE, van der Graaf Y, Eikelboom BC, Kappelle LJ, Mali WP. Carotid artery stenosis: accuracy of contrast-enhanced MR angiography for diagnosis. *Radiology.* 2003;228(3):677-682.
74. Nederkoorn PJ, Mali WP, Eikelboom BC, et al. Preoperative diagnosis of carotid artery stenosis: accuracy of noninvasive testing. *Stroke.* 2002;33(8):2003-2008.
75. Townsend TC, Saloner D, Pan XM, Rapp JH. Contrast material-enhanced MRA overestimates severity of carotid stenosis, compared with 3D time-of-flight MRA. *J Vasc Surg.* 2003;38(1):36-40.
76. Ansari SA, Schnell S, Carroll T, et al. Intracranial 4D flow MRI: toward individualized assessment of arteriovenous malformation hemodynamics and treatment-induced changes. *AJNR Am J Neuroradiol.* 2013;34(10):1922-1928.

77. Byrne G, Mut F, Cebral J. Quantifying the large-scale hemodynamics of intracranial aneurysms. *AJNR Am J Neuroradiol.* 2014;35(2):333-338.
78. Edjlali M, Roca P, Rabrait C, et al. MR selective flow-tracking cartography: a postprocessing procedure applied to four-dimensional flow MR imaging for complete characterization of cranial dural arteriovenous fistulas. *Radiology.* 2014;270(1):261-268.
79. Markl M, Wu C, Hurley MC, et al. Cerebral arteriovenous malformation: complex 3D hemodynamics and 3D blood flow alterations during staged embolization. *J Magn Reson Imaging.* 2013;38(4):946-950.
80. Schnell S, Ansari SA, Vakil P, et al. Three-dimensional hemodynamics in intracranial aneurysms: influence of size and morphology. *J Magn Reson Imaging.* 2014;39(1):120-131.
81. DeMarco JK, Huston J, 3rd. Imaging of high-risk carotid artery plaques: current status and future directions. *Neurosurg Focus.* 2014;36(1):E1.
82. Etesami M, Hoi Y, Steinman DA, et al. Comparison of carotid plaque ulcer detection using contrast-enhanced and time-of-flight MRA techniques. *AJNR Am J Neuroradiol.* 2013;34(1):177-184.
83. Mughal MM, Khan MK, DeMarco JK, Majid A, Shamoun F, Abela GS. Symptomatic and asymptomatic carotid artery plaque. *Expert Rev Cardiovasc Ther.* 2011;9(10):1315-1330.
84. Qiao Y, Etesami M, Astor BC, Zeiler SR, Trout HH, 3rd, Wasserman BA. Carotid plaque neovascularization and hemorrhage detected by MR imaging are associated with recent cerebrovascular ischemic events. *AJNR Am J Neuroradiol.* 2012;33(4):755-760.
85. Singh N, Moody AR, Gladstone DJ, et al. Moderate carotid artery stenosis: MR imaging-depicted intraplaque hemorrhage predicts risk of cerebrovascular ischemic events in asymptomatic men. *Radiology.* 2009;252(2):502-508.
86. Wasserman BA. Advanced contrast-enhanced MRI for looking beyond the lumen to predict stroke: building a risk profile for carotid plaque. *Stroke.* 2010;41(10 Suppl):S12-16.
87. Obusez EC, Hui F, Hajj-Ali RA, et al. High-Resolution MRI Vessel Wall Imaging: Spatial and Temporal Patterns of Reversible Cerebral Vasoconstriction Syndrome and Central Nervous System Vasculitis. *AJNR Am J Neuroradiol.* 2014.
88. 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(9):1677-1683.
89. 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(2):286-291.
90. Eliasziw M, Smith RF, Singh N, Holdsworth DW, Fox AJ, Barnett HJ. Further comments on the measurement of carotid stenosis from angiograms. North American Symptomatic Carotid Endarterectomy Trial (NASCET) Group. *Stroke.* 1994;25(12):2445-2449.
91. Fox AJ. How to measure carotid stenosis. *Radiology.* 1993;186(2):316-318.
92. Bartlett ES, Walters TD, Symons SP, Fox AJ. Quantification of carotid stenosis on CT angiography. *AJNR Am J Neuroradiol.* 2006;27(1):13-19.
93. Sawyer-Glover AM, Shellock FG. Pre-MRI procedure screening: recommendations and safety considerations for biomedical implants and devices. *J Magn Reson Imaging.* 2000;12(1):92-106.
94. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology.* 2004;232(3):635-652.
95. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants, and Devices*. Los Angeles, Calif: Biomedical Research Publishing Group; 2005.
96. American College of Radiology. ACR-AAPM technical standard for diagnostic medical physics performance monitoring of magnetic resonance imaging (MRI). 2014; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Equip.pdf. Accessed November 21, 2014.

*Practice parameters and technical 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 practice parameters and technical

standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter
2000 (Resolution 11)
Revised 2005 (Resolution 7)
Amended 2006 (Resolution 35)
Revised 2010 (Resolution 21)
Amended 2012 (Resolution 8 – title)
Amended 2014 (Resolution 39)
Revised 2015 (Resolution 10)