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ACR–ASNR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF INTRACRANIAL MAGNETIC RESONANCE PERFUSION IMAGING

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

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

Perfusion imaging (MRI) is a proven and useful tool for the evaluation, assessment of severity, and follow-up of diseases of the central nervous system [1-8]. It can be performed with contrast administration, using dynamic susceptibility contrast (DSC) or dynamic contrast enhancement (DCE) techniques or without contrast administration, using arterial spin-labeling (ASL) techniques [1-4,6,7,9-12].

II. INDICATIONS

Primary indications for perfusion MRI of the brain include, but are not limited to, the following:

A. Assessment of Neurovascular Disease [1-4,6,7,13-17]
   1. Acute stroke (assessment of ischemic penumbra)
   2. Assessment of the cerebrovascular reserve using a challenge
   3. Hemodynamic significance of cervical or intracranial vascular stenosis
   4. Cervical or intracranial revascularization efficacy
   5. Vasospasm
   6. Cerebral arteriopathy (eg, vasculitis; moya-moya)
   7. Vascular malformations

B. Diagnosis and Characterization of Mass Lesions [6,13,15,18-22]
   1. Different diagnosis (tumor versus tumor mimic)
   2. Diagnosis of primary neoplasms (may include grading)
   3. Surgical planning (biopsy or resection)
      a. Targeting locations for biopsy
      b. Guiding resection extent
   4. Therapeutic follow-up
      a. Radiation necrosis versus recurrent or residual tumor
      b. Chemonecrosis versus recurrent or residual tumor
      c. Monitor potential transformation of nonresectable low-grade neoplasms to higher grade

C. Neurological Disorders Involving Alterations of the Brain Perfusion, in the Appropriate Clinical Setting [1,3,6,23-30]
   a. Alzheimer disease and other cognitive disorders
   b. Assessment of the effects of drugs used for treatment
   c. Migraine-associated hyperperfusion or hypoperfusion
   d. Epilepsy
   e. Head trauma
   f. Functional brain injury and functional brain mapping
   g. Encephalitis and other infectious diseases

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [31].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a MR Perfusion 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 – revised in 2016, Resolution 12-b)

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

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 for consultation. Patients should be screened and interviewed before the examination to exclude individuals who may be at risk by exposure to the MR environment.

Bolus perfusion studies require the intravenous (IV) administration of gadolinium-based contrast agents (GBCAs). GBCAs should be administered using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. In most cases, contrast administration via the right arm is preferred to reduce artifact from significant contrast agent reflux into the jugular vein [3]. Although GBCAs are widely used in pediatric patients, the physician responsible for administration should be aware that safety and efficacy of GBCAs are not as well established in children younger than 2 years as they are in older children and adults (see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [32] and the ACR Manual on Contrast Media [33].

Pediatric patients or patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation or general anesthesia may be needed to achieve a successful examination, particularly in young children. If moderate sedation is necessary, refer to the ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia [34].

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 [1,3,5-9,11-13,15,17-22,24,26-30,35-53]

1. Dynamic susceptibility contrast MRI (DSC MRI) T2* perfusion (also known as bolus-tracking MRI) [1-3,5-7,9,13,15,19,36,45,46]
    a. Technique

    The DSC MRI perfusion technique is the most commonly utilized technique for MR perfusion imaging. It is used in the setting of infarct and tumor, as well as other conditions with altered cerebrovascular hemodynamics, because it estimates parameters such as cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT). It is based on the principles of tracer kinetic modeling to assess the cerebral microvasculature. In DSC perfusion imaging, GBCA is injected intravenously and monitored as it passes through the microvasculature.

    The most common method to perform DSC MRI is a single-shot gradient-echo echoplanar sequence, which

permits acquisition of an entire image slice with only a single radiofrequency excitation. TE should be based on optimization of T2* contrast for the field strength at which imaging is performed. In DSC, images are acquired dynamically during the passage of GBCA through the brain. Image contrast is based on gadolinium's magnetic susceptibility effect. Typically, approximately 10 seconds after the beginning of image acquisition, 0.1 mmol/kg of a GBCA is administered via a peripheral IV catheter. The injection rate in adults is typically 4 to 5 mL/s, using a power injector to assure standard, reproducible GBCA bolus administration. Following IV GBCA bolus, rapid repeated imaging of the tissue (most commonly brain) is performed during the first pass of the contrast bolus. Series of images are acquired with the signal in each voxel representing intrinsic tissue T2/T2* signal attenuated by the susceptibility-induced signal loss proportional to the amount of contrast primarily in the microvasculature (capillaries). This differs from the DCE MRI perfusion technique, in which there is increase in T1-weighted signal intensity proportional to the contrast concentration [3,6]. Ideally, images should be obtained at least once every 1.5 seconds. A sufficient number of repetitions should be acquired to capture the entire first pass of the contrast bolus—typically 40 repetitions at a TR = 1.5 seconds. Examples may be found in the literature [7,36,45]. Relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF) are commonly obtained using region-of-interest approaches, comparing CBV or CBF in the lesion with contralateral normal brain or normal-appearing white matter.

Spin-echo (SE) versus gradient-echo (GE) techniques [6,8,13,15,19,22,48,54]
Both GE and SE echo-planar images (EPI) can be used for DSC-MRI. GE-DSC techniques are more sensitive to larger vessels such as veins, whereas SC-DSC sequences are more sensitive to smaller vessels (capillaries) that should be more specific for tumor vessels. In reality, tumor vessels are large enough that GE-DSC better demonstrates tumor vessels than SE-DSC. However, GE-DSC can be challenging after surgery because of signal loss and artifact from postoperative hemorrhage or metallic foreign bodies. Recently, the two techniques have been combined to provide simultaneous perfusion and permeability measurements using spin- and gradient-echo (SAGE) EPI MRI.

3T versus 1.5T [19]
DSC MR perfusion imaging with 3T yields higher signal-to-noise ratio (SNR) for a given dose of contrast. Thus, less contrast can be used in patients with limited renal function. However, 3T also causes increased T1 effects and can underestimate contrast leakage from blood-brain barrier (BBB) disruption. Field strength should be taken into account when composing perfusion rCBV maps acquired on different MRI machines.

b. Data processing
The processing of the DSC data requires a dedicated software package. Multiple processing packages are available commercially. Some software packages are better suited for cerebrovascular applications of DSC, and others are better suited for brain tumor applications. The different software packages rely on different kinetic analysis models [19]. The packages calculate CBV, CBF, MTT, Tmax, and other parameters and create color maps of regional perfusion [7].

c. Interpretation
In stroke imaging, areas of prolonged MTT correspond to areas of hypoperfused, at-risk brain tissue. The difference between the perfusion abnormality and the diffusion abnormality reflects the ischemic penumbra around the infarct core. Areas of decreased CBV correlate best with areas of irreversible ischemic change (infarct core).

To assess the hemodynamic significance of an arterial stenosis or occlusion, pharmacologic challenge testing may be useful. In general, such testing entails comparison of DSC performed before and after administration of a vasodilatory agent such as acetazolamide. The decision to perform challenge testing should be made in light of the patient's overall cardiovascular status and should take place under physician supervision [14,16].

The CBV and CBF parameters can also be used to assess the degree of tumor angiogenesis as a marker of tumor grade, histology, and prognosis, especially in gliomas. The rCBV measurements are the most

important of the perfusion images for analyzing brain tumors and have been shown to correlate with tumor grade and histologic findings of increased tumor vascularity. Vasculature is a key histopathologic feature in the diagnosis of glioma, and perfusion-weighted imaging aids in the grading of these tumors preoperatively. MR perfusion imaging can estimate the volume of blood that passes through the capillary bed per unit of time. In general, higher-grade tumors have increased blood vessels and increased blood volume. With higher-grade tumors, there is increased loss of BBB integrity, associated in turn with increased contrast leakage and enhancement. Contrast-agent extravasation due to BBB disruption is one of the main challenges of DSC, because it can result in overestimation of the CBV value. Increased loss of BBB integrity in high-grade tumors is associated with increased contrast leakage and enhancement. An initial GBCA dose of approximately 0.05 mmol/kg may be injected before the DSC injection in order to correct for anticipated leakage effects. Alternatively, intravascular blood pool agents may be considered to evaluate perfusion, although these agents limit evaluation of BBB leakage. Other disadvantages of DSC include susceptibility artifacts (ie, blood products, calcification, air, metal, and bone) and operator dependence [3,6,46,49].

2. DCE MRI, also known as "permeability" MRI – T1 permeability mapping [10,55-59]

   a. The DCE MRI perfusion technique is typically used in the setting of tumor evaluation because it allows estimation of tissue (microvascular and BBB) permeability and allows assessment of tumor angiogenesis. DCE MRI depicts the wash-in, plateau, and wash-out contrast kinetics of the tissue, providing information at the microvascular level of the tissue evaluated [3]. It is useful in evaluation of tumor grade and histology, drug therapy, treatment response to radiation and chemotherapy, and in differentiating tumor recurrence from radiation necrosis [2,13,20]. This technique calculates perfusion parameters by evaluating T1 shortening caused by a bolus of GBCA passing through tissue of interest. Serial T1-weighted images are acquired before, during, and after administration of GBCA agent. The acquired signal intensity-time curve reflects a composite of tissue perfusion, vessel permeability, and extravascular-extracellular space. The most commonly calculated parameter is k-trans.

   b. Technique [3,5,17,22,51]
   The most common method to perform DCE MRI uses a fast T1-weighted GE sequence with short TE (<1.5 ms) and TR (<7 ms) and flip angle around 30°. A temporal resolution of 5 to 10 seconds for obtaining a series of 2-D slices or a single 3-D slab is possible with current technology while preserving spatial resolution. Obtaining a T1 map, commonly using a precontrast lower flip angle data set, improves the accuracy of GBCA concentration calculations and quantification. The use of a power injector for bolus (2 to 5 cc/second) or infusion (30 to 60 seconds) technique ensures reproducible and standardized GBCA administration. Because there is potential for leakage effects that can cause the CBV measurements performed for DSC MRI to be overestimated or underestimated (see V.C.1.a), DCE MRI is typically performed before the DSC MRI. This ordering also allows for saturation of the extravascular space, providing for more accurate quantification of metrics such as rCBV from DSC MRI. DCE MR perfusion imaging depicts wash-in, plateau, and wash-out contrast kinetics of the tissue. It is based on a two-compartmental (plasma space and extravascular extracellular space) pharmacokinetic model.

   c. Data processing [3,5,17,22,51]
   The determination of an AIF to obtain more accurate *C(t)* can be a challenge in DCE imaging. Ideally, the AIF would be determined in each patient using the dynamic curve of the carotid or middle cerebral artery. However, if this is not possible, the AIF can be approximated from the superior sagittal sinus, with the understanding that this will introduce some error in the compartmental model output. The plasma concentration curve can be further fitted—eg, to biexponential form (as in the Tofts model). The general steps include (in order): 1) perform baseline T1 mapping, 2) acquire DCE MR perfusion image, 3) convert signal intensity data to gadolinium concentration, 4) determine vascular input function, and 5) perform pharmacokinetic modeling. Using these data, several metrics are derived: 1) the transfer constant (k-trans), 2) the functional volume of the extravascular-extracellular space (Ve), 3) the rate constant (K-ep, where K-ep = k-trans/Ve), and 4) the fractional volume of the plasma space (Vp).

   There are also "reference tissue" models that attempt to estimate the vascular tracer concentration from

one or more normal-appearing surrounding tissues. DCE can be reviewed qualitatively by characterizing the T1 signal intensity curves over time, or various DCE MRI quantitative metrics can also be estimated. The typical parameters that can be estimated from the DCE MRI include k-trans (vascular permeability), EES (extravascular, extracellular space), Vp (plasma volume), and the k-ep (k-trans/EES). In general, malignant neoplasms will have a very high k-trans and Vp but lower EES, and more benign pathologies, including radiation necrosis, will have lower k-trans and Vp but higher EES.

3. ASL perfusion MRI [1,6,8,9,13,15,19,28-30,35,42,48,54]

ASL is most often utilized in the evaluation of functional imaging [13,24,26,27,41,44]. It is also used to evaluate treatment response in brain tumors. It is especially attractive because it does not require IV gadolinium contrast, given the ongoing concerns for gadolinium deposition and nephrogenic systemic fibrosis. It is useful, for instance, in patients with poor IV access, severely impaired renal function, pediatric patients, and pregnant women.

a. Technique

ASL perfusion MRI uses magnetically labeled endogenous arterial blood water as a tracer to derive information on cerebral hemodynamics and does not require IV contrast. The parameter most commonly derived with this technique is CBF and tissue perfusion [31,59,60]. This is accomplished by manipulating the longitudinal magnetization of intravascular blood water in order to differentiate it from the tissue magnetization. ASL does not require the use of an exogenous contrast agent, can be performed within about a 5 minute acquisition time, and provides both qualitative and quantitative measures of CBF. Moreover, unlike contrast-based approaches, ASL can be repeated multiple times, for example, under different physiological conditions. Although either pulsed labeling (PASL) with an instantaneous spatially selective saturation or inversion pulse, or continuous labeling (CASL), most typically by flow driven adiabatic fast passage, have been used, pseudocontinuous (P-CASL) is now widely available and provides the important advantage of relative insensitivity to transit time variability [60].The velocity-selective ASL (VS-ASL) images are acquired both with and without magnetization labeling of arterial blood water. The subtle difference between images acquired with (labeled) and without (control) ASL can be modeled to derive a calculated CBF image showing perfusion in mL/min/100 g of tissue at each voxel [13,37,43,47,53].

b. Data processing

The main principle of ASL is to obtain a tagged (or labeled) and a control image in which the static tissue signals are identical, but the magnetization of the inflowing blood is different. The water molecules in the arterial blood are magnetically tagged (or labeled) by using a radiofrequency (RF) pulse to saturate water protons. Subtraction between tagged and control images eliminates the static/stationary signal. The remaining signals are in flowing arterial blood and are a linear measure to the perfusion, which is proportional to the CBF. With the ASL technique, the SNR is very low because the signal from the tagged blood is only 0.5% to 1.5% of the entire tissue signal. ASL must be acquired before GBCA since Gd will cause shortening and decreased signal in both the tagged and control images. ASL allows determination of absolute quantitative values of CBF. Permeability, which can be a significant detriment with DSC MR perfusion, is less of a concern with ASL, and ASL is less operator dependent. However, ASL has a lower SNR, requiring longer scanning times.

Analysis of the acquired ASL images can be performed using readily available software. The qualitative CBF map is created by subtracting the labeled images from the control images, resulting in an image with intensity proportional to CBF. The quantitative CBF in units of mL/min/100 g of tissue is much more challenging to measure and requires sophisticated software. Briefly, the equilibrium magnetization M0 of the arterial blood is estimated by fitting the control or unlabeled signal in the brain tissue to a saturation-recovery curve. The CBF is calculated by a fit of the signal difference (ΔM) to the perfusion model with the following values for the physical constants: R1 (longitudinal relaxation rate of tissue); R1a (longitudinal relaxation rate of blood); and λ (brain/blood partition coefficient of water).

4. Advantages, disadvantages, and comparison of MR perfusion techniques [3,6,13]
   The following tables within the reference articles serve as useful tools in comparing, contrasting, and summarizing the DSC, DCE, and ASL MRI perfusion techniques, the MR sequences utilized most commonly for each technique, and the advantages and disadvantages of each technique.
   a. Three Types of Perfusion MRI Technique (see Table 1 within reference [13])
   b. Imaging Sequences for Three Types of Perfusion MRI techniques (see Table 3 within reference [13])
   c. Advantages and Disadvantages of Perfusion Signals (see Table 7 within reference [13])
   d. Typical Sequences Used and Minor Practical Requirements (see Table 1 within reference [3])
   e. Advantages and Disadvantages of Current MR Perfusion Imaging Techniques (see Table 1 within reference [6])

5. Perfusion imaging in pediatric patients [38,39,61-64]
   The need for small-caliber IVs, IV access in hands and feet, and small caliber PICC lines in infants and small children limits the use of automated power injectors, and in such situations, manual injection should be considered to avoid extravasation of contrast and damage to precarious IV access. However, if the perfusion technique using GBCA is considered, fast injection rates are required for reasonably accurate calculation of DSC perfusion parameters. The radiologist should carefully consider whether GBCA should be given, conferring with the providers participating in the direct care of the patient, as needed. ASL should be considered as the first option, given the potential repeated exposures to GBCAs for children over their lifetime and the unknown potential risk of gadolinium deposition in brain tissue [38,39].

   Clinical applications include neonatal hypoxic ischemic encephalopathy, pediatric stroke and vascular malformations, epilepsy, and brain tumors [64]. It can help differentiate high- and low-grade tumors, reflect seizure-related perfusion changes, which may help find a region of focal cortical dysplasia with potential future applications that may include evaluation of silent ischemia in sickle cell patients, monitor changes in intracranial pressure in hydrocephalus, and provide additional insights in nonaccidental trauma and chronic traumatic brain injury.

   ASL offers many advantages benefiting the pediatric population because there is no need for IV contrast or radiotracer administration, eliminating the need for needlestick or IV access, lack of radiation, and an easy ability to repeat imaging in the event of motion degradation, as well as improved quality secondary to decreased susceptibility artifact at the skull base due to immature paranasal sinus development [64].

   Although ASL is preferred in perfusion and vascular imaging in the pediatric population, DSC perfusion MRI is the most commonly technique used for evaluation of pediatric brain tumors. Perfusion models based on parameters derived from adults have been applied to children, and age-related normative values for CBF in children are just starting to be established. The effects of general anesthesia or conscious sedation on cerebral perfusion are complex, with certain anesthetic agents such as propofol associated with reversal of usual age-related decreases in CBF and CBV in children [62].

   Special considerations in interpreting perfusion studies in infants and young children include congenital heart disease involving right to left shunts, age-related changes in flow velocity, and sickle cell anemia in which flow velocity is typically elevated. The use of rCBV has limited application in pediatric brain tumors because of the predominance of astrocytic tumors of low-grade and the high prevalence of nonastrocytic tumors [38,39].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [65]

Reports should specify the perfusion technique employed and may optionally include volume of contrast and rate of injection. Specification of the hemodynamic parameters (eg, CBV, Tmax, etc) examined and whether qualitative review of parameter maps and/or extraction of time-intensity curves or quantitative values were employed should be specified. Relevant postprocessed images/maps depicting hemodynamic parameters should be archived in the same

manner as the study images.

VI. EQUIPMENT SPECIFICATIONS

Equipment monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance (MR) Imaging Equipment [66].

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

Specific policies and procedures related to MRI safety should be in place along 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.

VII. SAFETY GUIDELINES

See the ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging (MRI) [31], the ACR Manual on MR Safety [67], the ACR–SPR Practice Parameter for the use of Intravascular Contrast Media [32], and the ACR Manual on Contrast Media [33].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis.

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 Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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Writing Committee – members represent their societies in the initial and final revision of this practice parameter

ACR
Kavita K. Erickson, MD, Chair
Adam Goldman-Yassen, MD
Max Wintermark, MD

ASNR
Gloria C. Chiang, MD
David S. Liebeskind, MD, FAAN, FAHA, FANA, FSVIN, FWSO

SPR
Mai-Lan Ho, MD
Srikala Narayanan, MD
Arastoo Vossough, MD, PhD
Pankaj Watal, MD

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

Steven W. Hetts, MD, Chair
Lubdha M. Shah, MD, Vice Chair
Ashley H. Aiken, MD
Sameer A. Ansari, MD, PhD
Kristine A. Blackham, MD
Gloria C Chiang, MD
Gerald Drocton, MD
Kavita K. Erickson, MD
Adam E. Flanders, MD
Masis Isikbay, MD, BS
Raymond K. Tu, MD, FACR
Max Wintermark, MD

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

Terry L. Levin, MD, FACR, Chair
John B. Amodio, MD, FACR
Jesse Berman, MD
Tara M. Catanzano, MB, BCh
Harris L. Cohen, MD, FACR
Kassa Darge, MD, PhD
Dorothy L. Gilbertson-Dahdal, MD
Lauren P. Golding, MD
Adam Goldman-Yassen, MD
Safwan S. Halabi, MD
Jane Sun Kim, MD
Jennifer A Knight, MD
Jessica Kurian, MD
Helen R. Nadel, MD
Erica Poletto, MD
Richard B. Towbin, MD, FACR
Andrew T. Trout, MD
Esben S. Vogelius, MD
Jason Wright, MD

John E. Jordan, MD, MPP, FACR, Chair, Commission on Neuroradiology
Richard A. Barth, MD, FACR, Chair, Commission on Pediatric Radiology
David B. Larson, MD, MBA, Chair, Commission on Quality and Safety
Mary S. Newell, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee
Neil U. Lall, MD, Chair
Daniel G. Gridley, MD, Co-Chair
Richard A. Barth, MD, FACR
Gloria C. Chiang, MD
Timothy A. Crummy, MD, FACR
Kavita K. Erickson, MD
Adam Goldman-Yassen, MD
Steven W. Hetts, MD
Mai-Lan Ho, MD
John E. Jordan, MD, MPP, FACR
Amy L. Kotsenas, MD, FACR
David B. Larson, MD, MBA
Paul A. Larson, MD, FACR
Terry L. Levin, MD, FACR
David S. Liebeskind, MD, FAAN, FAHA
Srikala Narayanan, MD
Mary S. Newell, MD, FACR
Lubdha M. Shah, MD
Arastoo Vossough, MD, PhD
Pankaj Watal, MD
Max Wintermark, MD

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