

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Seizures and Epilepsy

Variant 1: Medically refractory epilepsy; surgical candidate and/or surgical planning.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8		O
MRI head without and with contrast	8	See statement regarding contrast in text under "Anticipated Exceptions."	O
FDG-PET head	7	May be helpful in preoperative planning.	⊕⊕⊕⊕
CT head without and with contrast	6		⊕⊕⊕
MRI functional (fMRI) head	6	May be helpful in preoperative planning.	O
MEG/MSI	6	May identify IOZ in nonlesional patients (normal MRI), can provide confirmatory localization information, may guide placement of iEEG. May substitute for invasive testing, and may be useful when other tests are discordant.	O
Tc-99m HMPAO SPECT head	5	May provide confirmatory localization information.	⊕⊕⊕⊕
CT head without contrast	5		⊕⊕⊕
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: New-onset seizure, unrelated to trauma. EtOH, and/or drug related.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head without and with contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	⊕⊕⊕
CT head without contrast	5	In the acute or emergency setting, CT may be the imaging study of choice.	⊕⊕⊕
MRI functional (fMRI) head	2		O
Tc-99m HMPAO SPECT head	2		⊕⊕⊕⊕
FDG-PET head	2		⊕⊕⊕⊕
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition:**Seizures and Epilepsy****Variant 3:****New-onset seizure, unrelated to trauma. Age 18-40.**

Radiologic Procedure	Rating	Comments	<u>RRL*</u>
MRI head without contrast	8	In the acute or emergency setting, CT may be the imaging study of choice.	O
MRI head without and with contrast	7	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in text under "Anticipated Exceptions."	O
CT head without and with contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
CT head without contrast	5	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
Tc-99m HMPAO SPECT head	4		☼☼☼☼
FDG-PET head	4		☼☼☼☼
MRI functional (fMRI) head	2		O
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 4:**New-onset seizure, unrelated to trauma. Older than age 40.**

Radiologic Procedure	Rating	Comments	<u>RRL*</u>
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head without contrast	5	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
Tc-99m HMPAO SPECT head	4		☼☼☼☼
FDG-PET head	4		☼☼☼☼
CT head without and with contrast	3	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
MRI functional (fMRI) head	2		O
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition:**Seizures and Epilepsy****Variant 5:****New-onset seizure, unrelated to trauma. Focal neurological deficit.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	8	If intravenous contrast is contraindicated. In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head without and with contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
CT head without contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	☼☼☼
Tc-99m HMPAO SPECT head	3		☼☼☼☼
FDG-PET head	3		☼☼☼☼
MRI functional (fMRI) head	2		O
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 6:**New-onset seizure. Older than age 18. Post-traumatic, acute.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		☼☼☼
MRI head without and with contrast	8	See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	If intravenous contrast is contraindicated.	O
CT head without and with contrast	5		☼☼☼
Tc-99m HMPAO SPECT head	2		☼☼☼☼
FDG-PET head	2		☼☼☼☼
MRI functional (fMRI) head	2		O
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition:**Seizures and Epilepsy****Variant 7:****New-onset seizure. Older than age 18. Post-traumatic, subacute or chronic.**

Radiologic Procedure	Rating	Comments	<u>RRL</u>*
MRI head without contrast	8	If intravenous contrast is contraindicated.	O
MRI head without and with contrast	8	See statement regarding contrast in text under "Anticipated Exceptions."	O
CT head without contrast	7		☼☼☼
CT head without and with contrast	6		☼☼☼
FDG-PET head	5		☼☼☼☼
MRI functional (fMRI) head	4		O
Tc-99m HMPAO SPECT head	2		☼☼☼☼
MEG/MSI	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

SEIZURES AND EPILEPSY

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Summary of Literature Review

Introduction/Background

A seizure is a finite event of altered cerebral function because of excessive and abnormal electrical discharges of the brain cells. Epilepsy is a chronic condition predisposing a person to recurrent seizures. Epilepsy is common, affecting approximately 2 million people in the United States at any one time with a world-wide age-adjusted incidence of 41-177/100,000 people per year [1]. It has been estimated that about 7%-8% of the population experiences at least one epileptic seizure during their lifetimes [2]. The basic mechanism of epileptic seizures has not been fully elucidated.

The classification of epileptic seizures by the International League Against Epilepsy was last revised in 2010 ([Tables 1 and 2](#)) [3]. The classification is important because etiologic diagnosis, appropriate treatment, and accurate prognostication all depend on the correct identification of seizures and epilepsy. There are two main types of seizures ([Table 1](#)): generalized and focal. Generalized seizures are further subdivided into tonic-clonic, absence, myoclonic, clonic, tonic, and atonic. The separation of “focal” from “generalized” seizures is a

useful construct — even if this separation is not truly distinct [3]. Generalized seizures rapidly affect both hemispheres, and both sides of the body — even when caused by a “focal” lesion. The older classification terms for focal seizures (‘simple partial,’ ‘complex partial,’ and ‘partial’) have been supplanted, and these distinctions have been removed [3]. Certain types of seizure disorders are likely to be associated with structural brain lesions, including tumors, infection, infarction, traumatic brain injury, vascular malformations, developmental abnormalities, and seizure-associated brain pathology ([Table 3](#)) [4]. Hence, knowledge of seizure types helps to determine whether neuroimaging is clinically indicated and what type of study is appropriate.

Computed Tomography/Magnetic Resonance Imaging

While the imaging evaluation of epilepsy was greatly advanced by the clinical introduction of computed tomography (CT) in the early 1970s [5-6] because of its superior soft-tissue contrast, multiplanar imaging capability, and lack of beam-hardening artifacts, virtually all the substrates of epilepsy are visualized with greater sensitivity and accuracy by magnetic resonance imaging (MRI) [7-15]. As a result, MRI has become the modality of choice for high-resolution structural imaging in epilepsy. Routine evaluation techniques of all clinically available scanner field strengths may be sufficient for determining mass lesions. However, optimized protocols for scans obtained on high-field (>1.5 T) scanners may be necessary for evaluating focal seizures (“partial complex epilepsy”). These patients require scrutiny of the hippocampus and temporal lobe for atrophy and subtle signal alteration, as well as for detecting certain structural abnormalities such as cortical dysplasias, hamartomas, and other developmental abnormalities [8-9,16-21]. Anatomic imaging identifies a focal abnormality in up to 51% of patients with focal seizures [22]. With the widespread clinical availability of high-performance MRI systems, a comprehensive MRI examination, with functional techniques providing additional information, adding corroborative information, and improving overall accuracy, may in the future be of even greater value in diagnosing epilepsy.

Functional Studies

Although the data provided by MRI are essential in the presurgical evaluation of patients with medically refractory epilepsy, structurally detectable abnormalities are absent in many patients. In these patients, functional studies provide useful information on the location of the seizure focus. Functional imaging techniques, including positron emission tomography (PET), single-photon emission computed tomography (SPECT), magnetic source imaging (MSI), and functional MRI (fMRI), have contributed to the presurgical evaluation of patients with epilepsy [18-20,23-41].

Clinical PET with fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG) provides a measure of glucose uptake and

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thus metabolism. A seizure focus will typically manifest as a focus of hypometabolism on interictal (between episodes of seizure activity) examinations and will be seen as a focus of increased metabolism on ictal (during seizure) examinations. Interictal FDG-PET is sensitive (84%) and specific (86%) by electroencephalogram (EEG) criteria to temporal lobe epilepsy (TLE) and 33% sensitive and 95% specific to extratemporal epilepsy. By comparison, structural imaging using a variety of MR field strengths and techniques yielded a sensitivity of 55% and a specificity of 78%.

Both bolus MRI and SPECT that uses perfusion agents such as ^{99m}Tc-HMPAO or ^{99m}Tc-Neurolite, provide an assessment of regional cerebral blood flow rather than brain metabolism. A seizure focus will typically manifest as a focus of hypoperfusion on interictal examinations and will be seen as a focus of increased activity on ictal examinations. The utility of isolated interictal cerebral perfusion assessment in patients without anatomic imaging abnormality is limited [42-43]. The use of ictal/interictal subtraction imaging with coregistration on MRI and image-guided surgery datasets is proving to be more useful than interictal perfusion imaging alone [43]. Injection of the blood flow agent within 90 seconds of seizure onset does, however, appear to be required to demonstrate the expected localized increase in cerebral perfusion [44]. The use of perfusion techniques in epilepsy is therefore limited because of the technological challenge of injecting EEG-monitored patients within 90 seconds of seizure onset.

fMRI techniques include phosphorus and proton spectroscopy (MRS), perfusion, and blood oxygen level dependent (BOLD) activation. The widespread application of most of these techniques in clinical practice depends on the widespread availability of high-performance MR imagers capable of performing fast echo-planar pulse sequences (EPIs), as well as substantial data postprocessing capabilities.

MRS is a set of noninvasive techniques for in-vivo chemical analysis of the brain, some of which can be performed on standard-performance clinical MR units. Although MRS has been used extensively for the past 30 years in molecular physics and chemistry, its application to the study of epilepsy is relatively recent. Widely available proton and phosphorus single-voxel techniques have consistently demonstrated metabolite changes in the epileptogenic region of the brain. MRS or chemical shift imaging (CSI) allows simultaneous acquisition of spectra from all brain regions. The pictorial display of MRS information facilitates comparison of the epileptogenic zone with the remainder of the brain and provides localizing information. CSI is not yet widely available in clinical practice. Initial studies suggest that both proton and phosphorus MRS may be useful adjunctive presurgical tests for localizing seizure foci in patients with partial epilepsy, particularly in difficult cases, potentially reducing the need for intracranial-depth electrode EEG recordings, and those with extratemporal seizure foci [19,25-26,32-33,35].

Only EEG (using either scalp electrodes or intracranial electrodes [iEEG]) and magnetoencephalography (MEG) directly measure the brain's electrical activity. As such, they could or should be the gold standard for localization. In terms of outcome, being "seizure free" is an appropriate metric. Both EEG and MEG offer significantly higher temporal resolution (ms), as compared with PET, SPECT, and fMRI, which are poor by comparison (sec-min). Recent improvements in MEG technology — with advanced electronics and 100-300 or more channels of whole-head magnetometers — now allow complete brain coverage and overlay of source information on magnetic source images (MSIs). Recent articles in the radiology literature describe both the techniques and the advantages of including MEG in the preoperative evaluation of patients with intractable or medically refractory seizures [45]. The MEG images are often superimposed on high-resolution MRI images. MEG is not a "frontline" tool for evaluation of epilepsy. A literature review supports some utility for MEG in the subset of patients who: a) are surgical candidates for resection, b) do not have a lesion identified on MRI or have multiple potential seizure foci, or c) are candidates for invasive monitoring (iEEG).

MEG is thus complementary to EEG and may provide confirmatory information for the ictal onset zone (IOZ) localization for potential lesions seen on MRI. MEG provides better spatial resolution (2-3 mm) as compared to EEG (7-10 mm) [46]. MEG can also guide the placement of iEEG grids; and in certain patients, it may help distinguish among multiple potential seizure foci.

The use and utility of MEG are growing, but are by no means settled. Many of the strong advocates for MEG have become familiar with the technique from their own research and have made their own contributions to this literature [47-50]. Conversely, one review stated "There is insufficient evidence in the current literature to support the relationship between the use of MEG in surgical planning and seizure-free outcome after epilepsy surgery" [51]. It might well be emphasized that MEG has the most value in the hands of experienced users in epilepsy referral centers.

Summary

- This document addresses several subsets of patients with seizures and epilepsy.
- Special circumstances include both acute and subacute to chronic post-traumatic seizures (Variants 6 and 7); seizure associated with neurologic deficit (Variant 5); and, presurgical evaluation (Variant 1).
- Presurgical evaluation and planning deserves special attention. fMRI may be most useful in surgical planning to avoid damage to critical structures.
- Most patients with temporal lobe epilepsy will have an anatomic or structural lesion identified by MRI — most often mesial temporal sclerosis, cortical dysplasia, or neoplasm.

- Many patients with nontemporal lobe epilepsy may not show a convincing structural lesion.
- Some patients may have more than one lesion and/or discordance between electrical findings on EEG and imaging localization. In these types of special circumstances FDG-PET, MEG, and SPECT imaging may help define the most likely ictal onset zone.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m²), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m². For more information, please see the [ACR Manual on Contrast Media](#) [52].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria[®] [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☼	<0.1 mSv	<0.03 mSv
☼☼	0.1-1 mSv	0.03-0.3 mSv
☼☼☼	1-10 mSv	0.3-3 mSv
☼☼☼☼	10-30 mSv	3-10 mSv
☼☼☼☼☼	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

Supporting Document(s)

- [ACR Appropriateness Criteria[®] Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Table 1. Classification of Seizures^a [3]

Generalized seizures

Tonic-clonic (in any combination)

Absence

Typical

Atypical

Absence with special features

Myoclonic absence

Eyelid myoclonia

Myoclonic

Myoclonic

Myoclonic atonic

Myoclonic tonic

Clonic

Tonic

Atonic

Focal seizures

Unknown

Epileptic spasms

^aSeizure that cannot be clearly diagnosed into one of the preceding categories should be considered unclassified until further information allows their accurate diagnosis. This is not considered a classification category, however.

Table 2. Descriptors of Focal Seizures According to Degree of Impairment During Seizure^a [3]

Without impairment of consciousness or awareness

With observable motor or autonomic components. This roughly corresponds to the concept of “simple partial seizure. “Focal motor” and “autonomic” are terms that may adequately convey this concept depending on the seizure manifestations).

Involving subjective sensory or psychic phenomena only. This corresponds to the concept of an aura, a term endorsed in the 2001 Glossary.

With impairment of consciousness or awareness. This roughly corresponds to the concept of complex partial seizure.

“Dyscognitive” is a term that has been proposed for this concept (Blume et al., 2001).

Evolving to a bilateral, convulsive^b seizure (involving tonic, clonic, or tonic and clonic components). This expression replaces the term “secondarily generalized seizure.”

^aFor more descriptors that have been clearly defined and recommended for use, please see Blume et al., 2001.

^bThe term “convulsive” was considered a lay term in the Glossary; however, we note that it is used throughout medicine in various forms and translates well across many languages. Its use is, therefore, endorsed.

Table 3. Electroclinical Syndromes and Other Epilepsies [3]

Electroclinical syndromes arranged by age at onset^a

Neonatal period

- Benign familial neonatal epilepsy (BFNE)
- Early myoclonic encephalopathy (EME)
- Ohtahara syndrome

Infancy

- Epilepsy of infancy with migrating focal seizures
- West syndrome
- Myoclonic epilepsy in infancy (MEI)
- Benign infantile epilepsy
- Benign familial infantile epilepsy
- Dravet syndrome
- Myoclonic encephalopathy in nonprogressive disorders

Childhood

- Febrile seizures plus (FS+) (can start in infancy)
- Panayiotopoulos syndrome
- Epilepsy with myoclonic atonic (previously astatic) seizures
- Benign epilepsy with centrotemporal spikes (BECTS)
- Autosomal-dominant nocturnal frontal lobe epilepsy (ADNFLE)
- Late onset childhood occipital epilepsy (Gastaut type)
- Epilepsy with myoclonic absences
- Lennox-Gastaut syndrome
- Epileptic encephalopathy with continuous spike-and-wave during sleep (CSWS)^b
- Landau-Kleffner syndrome (LKS)
- Childhood absence epilepsy (CAE)

Adolescence – Adult

- Juvenile absence epilepsy (JAE)
- Juvenile myoclonic epilepsy (JME)
- Epilepsy with generalized tonic-clonic seizures alone
- Progressive myoclonus epilepsies (PME)
- Autosomal dominant epilepsy with auditory features (ADEAF)
- Other familial temporal lobe epilepsies

Less specific age relationship

- Familial focal epilepsy with variable foci (childhood to adult)
- Reflex epilepsies

Distinctive constellations

- Mesial temporal lobe epilepsy with hippocampal sclerosis (MTLE with HS)
- Rasmussen syndrome
- Gelastic seizures with hypothalamic hamartoma
- Hemicconvulsion-hemiplegia-epilepsy

Epilepsies that *do not* fit into any of these diagnostic categories can be distinguished first on the basis of the presence or absence of a known structural or metabolic condition (presumed cause) and then on the basis of the primary mode of seizure onset (generalized vs. focal)

Epilepsies attributed to and organized by structural-metabolic causes

- Malformations of cortical development (hemimegalencephaly, heterotopias, etc.)
- Neurocutaneous syndromes (tuberous sclerosis complex, Sturge-Weber, etc.)

- Tumor
- Infection
- Trauma

Angioma

- Perinatal insults
- Stroke
- Etc.

Epilepsies of unknown cause

Conditions with epileptic seizures that are traditionally not diagnosed as a form of epilepsy per se

- Benign neonatal seizures (BNS)
- Febrile seizures (FS)

^aThe arrangement of electroclinical syndromes does not reflect etiology.

^bSometime referred to as Electrical Status Epilepticus during Slow Sleep (ESES).