

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Seizures — Child

Variant 1: Neonatal seizures.

Radiologic Procedure	Rating	Comments	RRL*
US head	9		O
MRI head without IV contrast	5	Particularly for hypoxic ischemic encephalopathy (HIE) and congenital malformations.	O
MRI head without and with IV contrast	4		O
CT head without IV contrast	3		⊕⊕⊕
CT head without and with IV contrast	3		⊕⊕⊕⊕
CT head with IV contrast	3		⊕⊕⊕
FDG-PET/CT head	1		⊕⊕⊕⊕
SPECT head	1		⊕⊕⊕
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Simple febrile seizures.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	2		O
MRI head without and with IV contrast	2		O
CT head without IV contrast	2		⊕⊕⊕
CT head without and with IV contrast	2		⊕⊕⊕⊕
CT head with IV contrast	2		⊕⊕⊕
SPECT head	1		⊕⊕⊕
FDG-PET/CT head	1		⊕⊕⊕⊕
US head	1		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 — Child

Variant 3: Complex febrile seizures.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	4		O
MRI head without and with IV contrast	4		O
CT head without IV contrast	3		⊗⊗⊗
CT head without and with IV contrast	3		⊗⊗⊗⊗
CT head with IV contrast	3		⊗⊗⊗
SPECT head	2		⊗⊗⊗
FDG-PET/CT head	1		⊗⊗⊗⊗
US head	1		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: Post-traumatic seizures.

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	9		⊗⊗⊗
MRI head without IV contrast	5	Useful for detecting blood products and gliosis not seen on CT and in the chronic post-traumatic setting.	O
MRI head without and with IV contrast	3		O
CT head without and with IV contrast	2		⊗⊗⊗⊗
CT head with IV contrast	2		⊗⊗⊗
US head	1		O
FDG-PET/CT head	1		⊗⊗⊗⊗
SPECT head	1		⊗⊗⊗
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 — Child

Variant 5: Partial seizures.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	9		O
MRI head without and with IV contrast	7		O
CT head without and with IV contrast	5	If MRI is unavailable or contraindicated.	⊗⊗⊗⊗
CT head with IV contrast	5	If MRI is unavailable or contraindicated.	⊗⊗⊗
FDG-PET/CT head	5	Recurrent seizure.	⊗⊗⊗⊗
SPECT head	5	Recurrent seizure.	⊗⊗⊗
CT head without IV contrast	3	If MRI is unavailable or contraindicated.	⊗⊗⊗
US head	1		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: First generalized seizure (neurologically normal).

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	5		O
MRI head without and with IV contrast	4		O
CT head without IV contrast	4		⊗⊗⊗
CT head without and with IV contrast	2		⊗⊗⊗⊗⊗
CT head with IV contrast	2		⊗⊗⊗
SPECT head	1		⊗⊗⊗
FDG-PET/CT head	1		⊗⊗⊗⊗
US head	1		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 — Child

Variant 7: Generalized seizures (neurologically abnormal).

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	9		O
CT head without IV contrast	6		⊛⊛⊛
MRI head without and with IV contrast	6	To clarify an abnormality on the noncontrast MRI or if considering infection or inflammation.	O
FDG-PET/CT head	2		⊛⊛⊛⊛
CT head without and with IV contrast	2		⊛⊛⊛⊛
CT head with IV contrast	2		⊛⊛⊛
SPECT head	2		⊛⊛⊛
US head	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 8: Intractable or refractory seizures.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	9		O
MRI head without and with IV contrast	6	To clarify an abnormality on the noncontrast MRI or if considering infection or inflammation.	O
FDG-PET/CT head	6		⊛⊛⊛⊛
SPECT head	6		⊛⊛⊛
CT head without IV contrast	5		⊛⊛⊛
CT head without and with IV contrast	2		⊛⊛⊛⊛
CT head with IV contrast	2		⊛⊛⊛
US head	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

SEIZURES — CHILD

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Summary of Literature Review

Introduction/Background

Seizures present common management problems in medical practice, particularly in pediatrics. In the United States, about 120,000 individuals younger than age 18 have a first seizure each year [1]. Ten percent of the American population will experience a seizure during their lifetimes [1]. 45,000 cases of epilepsy are diagnosed in children younger than age 15 each year [1]. Epileptic seizures in children younger than age 10 are likely to be generalized, while epileptic seizures are more commonly partial in children older than age 10 [1].

Seizures are defined as “a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain” [2]. There are a number of classification schemes of seizures [3-6]. One frequently referenced is the International League Against Epilepsy (ILAE), as modified recently by the ILAE Classification Core Group [7]. However, none of the current classifications neatly fit into categories that can be used to propose imaging guidelines. To alleviate this problem, patients have been categorized into groups for which specific imaging modes seem appropriate. The groupings, which are described below, are based on patient age, precipitating event, and clinical manifestations of the seizure, coupled with electroencephalogram (EEG) findings.

Imaging Recommendations

The clinical manifestations of a seizure, in conjunction with an EEG, classify it as either generalized or partial. This is the most important distinction related to imaging. The historical data are sometimes limited, and accurate determination of specific seizure category may be difficult. The initial imaging of a patient presenting with a seizure may require supplemental imaging as the nature of the seizure becomes more defined, or if the seizures become more frequent or refractory to medical treatment.

Neonatal Seizure

The incidence of neonatal seizures has been estimated to be three per 1,000 live births per year. The rate is higher in preterm infants (57 to 132 per 1,000 live births) [8]. Hypoxic ischemic encephalopathy is by far the most common cause of seizure in both term and preterm infants. Intracranial hemorrhage is the second leading cause. Together they account for nearly 75% of seizures in the neonatal period. Approximately 90% of infants with hypoxic ischemic encephalopathy experience the onset of their seizures within two days following birth. Seizures occurring beyond the seventh day of life are more likely to be related to infection or developmental defects [9].

Ultrasound (US) is the mainstay for imaging the neonatal brain. Its portability and ease of evaluation at the bedside make it an ideal method of evaluation. US does not involve radiation exposure in these susceptible patients. Magnetic resonance imaging (MRI) is increasingly valuable, particularly in defining the extent of parenchymal injury [10,11]. Diffusion imaging has added sensitivity to routine spin-echo sequences [12]. In addition, MRI has the greatest sensitivity for detecting intracranial developmental abnormalities associated with seizures, including malformations of cortical development [13]. MRI-compatible incubators and the sophistication

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of neonatal care teams in managing critical neonates in the MRI environment have allowed for increased MRI use.

Computed tomography (CT) can play a role in defining the extent of hemorrhage and is useful in quantifying and characterizing extra-axial collections, but it involves ionizing radiation and is less sensitive than MRI for evaluating hypoxic ischemic events and structural anomalies.

Febrile Seizure

Between 2%-5% of children have febrile seizures. About one-third of them will have at least one recurrence. Febrile seizures occur between 3 months and 5 years of age and are associated with fever, but without evidence of intracranial infection or other defined cause. Simple febrile seizures last <15 minutes and do not recur within 24 hours. There is no indication for imaging simple febrile seizures. Complex febrile seizures (which are prolonged, recur more than once in 24 hours, or are focal) are rarely associated with underlying pathology such as meningitis, encephalitis, or child abuse. Brain abnormalities may lower seizure threshold in febrile children [14]. Imaging, preferably with MRI or CT, may be performed in selected patients with complex febrile seizures [15] when meningitis/encephalitis or underlying trauma is suspected.

It remains controversial whether febrile seizures, particularly prolonged complex febrile seizures, cause the later development of mesial temporal sclerosis (MTS). There is growing evidence that hippocampal swelling and restricted diffusion, which can be identified on coronal MRI, maybe associated with MTS later in life [16-18]. Such findings, however, are of little clinical significance at the time of the febrile event and do not assist in immediate patient management.

Post-traumatic Seizure

Seizures may occur secondary to intracranial trauma. CT and MRI both effectively define treatable pathology associated with intracranial trauma. In a study by Lee and Lui [19], CT identified 100% of the treatable lesions in patients with mild trauma as indicated by Glasgow coma scores of 13-15. In this study, although CT results were negative in 53% of patients, 7% of patients had lesions that required surgical intervention. MRI is generally less appropriate in the acute trauma setting, depending on the overall clinical status of the child. However, it can be useful in detecting intracranial blood as well as post-traumatic gliosis. An important subgroup to consider for CT evaluation is the patient younger than age 2 presenting to the emergency department with a first-time afebrile seizure, as this may be a presentation of nonaccidental trauma (child abuse).

Partial Seizure

The occurrence of a partial seizure implies an origin of the seizure in a focal (but not necessarily small) area of the brain, with a tendency for propagation [7]. Focality is also suggested through EEG analysis. Positive yields from imaging of patients with partial seizures, both simple (without loss of consciousness) and complex (with loss of consciousness), are considerably higher than those from imaging of patients with generalized seizures whose neurologic examination is normal [20,21]. In a study by Jan et al [22], neuroimaging was positive in more than 50% of patients whose seizures had focal features. MRI was considerably more sensitive than CT. Young et al [23] noted a 50% positivity rate for CT when neurologic findings were focal. Ibrahim et al [24] found seizures to be the presenting symptom in 12% of 81 consecutive children with primary brain tumors. Nine of 10 seizures in this series were focal.

Seizures can result from developmental abnormalities, hemorrhage, neoplasm, and gliosis, all of which can be detected by CT and MRI. MRI is considerably more sensitive than CT, particularly with subtle developmental abnormalities, small foci of hemorrhage, and metastases. The argument that CT is more accessible for emergent imaging of initial seizure is offset by the improved sensitivity of MRI. A study by Maytal et al [25] suggests limited justification for emergent CT as opposed to scheduled MRI in patients presenting with first-time seizure. One exception might be the patient younger than age 2 in whom the possibility of nonaccidental trauma (child abuse) should be considered. The rate of recurrence of partial seizures was considerably greater than that for generalized seizures. In a study by Hart et al [26] patients with partial seizures had a 94% rate of recurrence.

Both fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) and single-photon-emission computed tomography (SPECT) (ictal and interictal) can be helpful in evaluating recurrent seizures when anatomic imaging (CT and MRI) is normal. In general, however, functional imaging (FDG-PET, SPECT, functional MRI, and even magnetoencephalography) is most appropriately reserved for refined evaluation when surgical intervention is contemplated.

Generalized Seizure (less than two unprovoked seizures)

Patients with generalized seizures are divided into two subcategories: those who are neurologically normal and those who present with positive neurologic findings. Neurologic abnormalities may be historical, such as developmental delay or cerebral palsy. They may also be physical, as in postictal Todd's paralysis, or simply manifest as an abnormal sensorium. Fewer than 2% of patients will have an abnormal CT examination after a generalized seizure if they are neurologically normal with a negative EEG. In a study by Hirtz [27] none of the positive CT findings were treatable. In a study by Reinus et al [28] 100% of patients with abnormal studies had either a positive neurologic examination, a positive EEG, or a known malignancy. Young et al [23] reported only 6% positive CT examinations for generalized seizures, with nearly 50% positivity in focal epilepsy. Sharma et al [20] studied 500 consecutive patients presenting to an emergency department with their first afebrile seizure. They defined two clinically significant high-risk indicators of positive examination: 1) presence of predisposing condition, and 2) focal seizure. Only 2% of low-risk patients had positive imaging examinations.

Patients with generalized seizures with abnormal neurologic findings should be evaluated with MRI. A difficult task in the evaluation of seizures is discriminating a generalized seizure whose onset is precipitated by a focal epileptic event from one without a focal precipitant. Many of these patients, however, demonstrate either a postictal neurologic finding or other neurologic abnormality, including nonspecific findings such as developmental delay [23]. Although Hart et al [26] reported that 83% of patients younger than age 16 at the time of initial seizure experienced a second seizure, 100% of seizures associated with a neurologic deficit recurred.

Seizure Syndromes

A number of seizure syndromes probably do not require imaging because they are sufficiently characteristic to be diagnosed clinically or through specific EEG patterns. Benign rolandic seizures, benign occipital epilepsy, and juvenile myoclonic seizures are fairly characteristic and rarely benefit from imaging. Patients with the malignant form of rolandic seizure without typical EEG findings may benefit from imaging. MRI is most likely positive when the EEG shows focal abnormality. West syndrome has been divided into symptomatic and asymptomatic forms. There are conflicting data as to the utility of SPECT and FDG-PET in the evaluation of West syndrome (also known as infantile spasms) [29]. MRI is probably indicated in symptomatic forms because there is a significant incidence of cortical dysplasia that can benefit from surgical management. Children presenting with absence seizures along with classic EEGs do not need to be imaged.

Intractable or Refractory Seizures

Refractory seizures, which are potentially treatable by surgical intervention, define a small percentage of patients with seizures or epilepsy. In these patients, the use of both anatomical and functional imaging modalities is needed in selected cases. MRI is considered the most sensitive and specific anatomic imaging technique in the evaluation of these patients. It is more sensitive (84%) than SPECT (75%), which is somewhat more sensitive than CT (62%) [30], in surgical patients with intractable seizures. MRI is particularly useful in the evaluation of MTS, periventricular white matter abnormalities, and cortical abnormalities which may be the cause of refractory seizures [31,32].

Ictal SPECT has been useful in differentiating temporal lobe epilepsy from extratemporal lobe foci and provides noninvasive imaging information used in planning treatment strategies. Ictal SPECT optimization requires radiopharmaceutical injection (Tc-99m HMPAO or Tc-99m ethyl cysteinyl dimer [ECD]) within seconds of a seizure. This practical limitation has made ictal imaging difficult, except in specialized inpatient centers [33,34]. There is general agreement that the combination of ictal and interictal SPECT is the optimal method of SPECT imaging in the evaluation of seizure focus [35]. Pharmacologic provocation of a seizure focus has been studied as a way to more reliably obtain a true ictal examination [36]. FDG-PET is an alternative to SPECT for functional imaging and is most useful in patients with intractable partial epilepsy [37]. Evidence that FDG-PET has prognostic value regarding the outcome of epilepsy surgery in refractory partial epilepsy is beginning to accumulate [3]. In particular, FDG-PET has been shown to be useful in evaluating residual foci of seizure activity in patients who have undergone unsuccessful surgical intervention [38]. SPECT is currently more available than PET, although the emergence of PET/CT has resulted in its increased availability. Both SPECT and FDG-PET have been used in some centers as a part of presurgical evaluation and planning.

Summary

- The appropriate imaging of pediatric patients being evaluated for seizures is variable and depends on the age at presentation, the seizure characteristics, the precipitating event, and the associated neurologic findings.

- US should be the first imaging modality for evaluating neonatal seizures. MRI should be considered in these children because it can detect a high percentage of abnormalities.
- MRI is more sensitive than CT in defining structural abnormalities associated with a seizure focus.
- Imaging, preferentially MRI, is indicated in partial seizures and generalized seizures accompanied by abnormal neurologic findings or other risk factors [39,40].
- Simple febrile seizures do not require imaging evaluation.
- In selected cases, when infection or trauma is suspected, complex febrile seizures can be evaluated with MRI or CT.
- Post-traumatic seizures should first be evaluated by CT. Late post-traumatic seizures may be better evaluated by MRI.
- Refractory or intractable seizures are best imaged with MRI followed by a functional study such as SPECT or PET.

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
○	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 “Varies”.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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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.