American College of Radiology
ACR Appropriateness Criteria®
Seizures-Child

Variant 1: **Neonatal seizures, age 0 to 29 days. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
US head	May Be Appropriate	O
MRI head without and with IV contrast	May Be Appropriate	O
CT head without IV contrast	May Be Appropriate	☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 2: **Children 6 months to 5 years of age. Simple febrile seizures. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 3: **Children 6 months to 5 years of age. Complex febrile seizures. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	May Be Appropriate	O
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 4: **Children 1 month to 17 years of age. Post-traumatic seizures, not including abusive head trauma. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
CT head without IV contrast	Usually Appropriate	☢☢☢
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 5: **Children 1 month to 17 years of age. Focal seizures, not including abusive head trauma. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
MRI head without and with IV contrast	May Be Appropriate (Disagreement)	O
CT head without IV contrast	May Be Appropriate	☢☢☢
US head	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 6: **Children 1 month to 17 years of age. Primary generalized seizure (neurologically normal). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	May Be Appropriate	O
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 7: **Children 1 month to 17 years of age. Generalized seizure (neurologically abnormal). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
MRI head without and with IV contrast	May Be Appropriate	O
CT head without IV contrast	May Be Appropriate	☢☢☢
US head	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
HMPAO SPECT or SPECT/CT brain	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

Variant 8: **Children 1 month to 17 years of age. Intractable seizures or refractory epilepsy.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
MRI head without and with IV contrast	May Be Appropriate (Disagreement)	O
HMPAO SPECT or SPECT/CT brain	May Be Appropriate	☢☢☢☢
FDG-PET/CT brain	May Be Appropriate	☢☢☢☢
US head	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢

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Summary of Literature Review

Introduction/Background

Epilepsy is defined as recurrent and unprovoked seizures and is one of the most common neurologic disorders. Status epilepticus is the most common neurologic emergency in children. The Centers for Disease Control and Prevention estimate that approximately 470,000 or 0.6% of children <17 years of age suffer from epilepsy, and approximately 50,000 new cases are being diagnosed in this age group every year [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]. In children, seizures represent an extremely heterogeneous group of medical conditions ranging from benign cases, such as a simple febrile seizure, to life-threatening situations, such as status epilepticus. Similarly, the underlying cause of seizures may range from idiopathic cases, usually genetic, to a wide variety of acute and chronic intracranial or systemic abnormalities, which may require therapeutic intervention to prevent morbidity and mortality.

The most commonly used classification system of seizure types is the one developed by the International League Against Epilepsy that recently underwent a revision with several nomenclature changes implemented [3]. The variants in this document take into consideration different scenarios at the time of a child's presentation, including patient's age, precipitating event (if any), and clinical and electroencephalogram (EEG) findings. This practical approach guides the clinician in clinical decision-making and helps identify efficient and appropriate imaging workup. For more information on the use of gadolinium, please refer to the ACR Manual on Contrast Media [4].

Initial Imaging Definition

Imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Neonatal seizures, age 0 to 29 days. Initial imaging.

The incidence of neonatal seizures has been estimated to be 3 per 1,000 live births per year [5]. The incidence is higher in preterm infants (57 to 132 per 1,000 live births) [6]. In the neonatal age group, seizures from acute symptomatic causes are much more common than neonatal idiopathic epilepsies [7]. Studies demonstrate that an

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underlying cause can be identified in about 95% of neonatal seizures [5,8]. The most common etiologies for neonatal seizures include hypoxic ischemic injury, by far the most common cause of seizures in both term and preterm infants (46%–65%) [5,8,9], followed by intracranial hemorrhage and perinatal ischemic stroke (10%–12%) [5,8]. Approximately 90% of infants with hypoxic ischemic encephalopathy experience seizure onset within 2 days after birth. Seizures occurring beyond the seventh day of life are more likely to be related to infection, genetic disorders, or malformations of cortical development [9].

US Head

Ultrasound (US) may be a useful initial imaging modality for the preterm and term-born neonatal brain, particularly if the infant is unstable or unable to have an MRI. The portability and ease of sonographic evaluation at the bedside renders a quick initial evaluation of a neonate presenting with seizures [10]. US allows identification of intraventricular hemorrhage, hydrocephalus, and white matter changes, such as cystic periventricular leukomalacia, and detects most abnormalities that have been associated with abnormal neurodevelopmental outcome especially in very preterm infants <32 weeks' gestation [11,12]. Limitations of US include its low sensitivity for hypoxic ischemic injury [7,11] as well as limited ability to visualize small infarctions, congenital developmental brain anomalies, and encephalitis. In neonates with seizures, cranial US alone identifies an etiology in approximately 38% of cases [8].

MRI Head

MRI is utilized to evaluate the extent and characteristics of parenchymal brain abnormalities in neonates with seizures [10]. Because hypoxic ischemic encephalopathy is the most common cause of neonatal seizures, diffusion-weighted imaging is the most sensitive sequence to detect an abnormality when performed at the appropriate time-interval [13]. In addition, MRI has the greatest sensitivity for detecting intracranial developmental abnormalities associated with seizures, including malformations of cortical development [14]. In a study of neonates with seizures, MRI showed findings in 11.9% of patients which were not apparent on cranial US, and in 39.8% of patients, MRI contributed to a diagnosis by providing information additional to cranial US [8]. Data are being accumulated establishing the prognostic value of MRI in neonates with seizures that demonstrates that the absence of major cerebral lesions on MRI is highly predictive of a normal neurological outcome [5,15]. There are potential risks associated with performing MRI in neonates who are in the intensive care unit, including the risks associated with transportation, positioning, and sedation of the patient in the setting of physiologic instability. The use of MRI-compatible incubators and small footprint MRI scanners can help with safer transportation and imaging of the patient.

CT Head

CT has a limited but specific role in the evaluation of neonates with seizures. A noncontrast CT can be performed to detect hemorrhagic lesions in the encephalopathic infant with a history of birth trauma, low hematocrit, or coagulopathy. CT may help to define the extent of intracranial hemorrhage and is useful in quantifying and characterizing extra-axial collections, but CT is less sensitive than MRI for detecting hypoxic ischemic events and structural anomalies [7]. CT is helpful in identifying calcifications in a suspected intrauterine infection, any associated traumatic abnormalities, and in the identification of dural sinus thrombosis. CT is rapid, does not require sedation, and may provide better assessment of the brain compared with US in scenarios in which acute hemorrhage, stroke, or hydrocephalus is suspected.

FDG-PET/CT Brain

There is no relevant literature to support the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT in the workup of a neonate with seizures.

HMPAO SPECT or SPECT/CT Brain

There is no relevant literature to support the use of Tc-99m hexamethylpropyleneamine oxime (HMPAO) single-photon emission computed tomography (SPECT) or SPECT/CT in the workup of a neonate with seizures.

Variant 2: Children 6 months to 5 years of age. Simple febrile seizures. Initial imaging.

Febrile seizures are relatively common events in the general pediatric population. Between 2% to 5% of children have febrile seizures, and about one-third of them will have at least one recurrence. Febrile seizures occur between 6 months and 5 years [16] of age and are associated with fever (temperature ≥100.4°F or 38°C by any method), but without evidence of intracranial infection or other defined cause. Simple febrile seizures are defined as a generalized seizure that lasts <15 minutes and do not recur within 24 hours. There is no indication for imaging of simple febrile seizures [16,17].

US Head
There is no relevant literature to support the use of US in the workup of a child with simple febrile seizures.

MRI Head
MRI is not indicated in the workup of a child with simple febrile seizures. In a small prospective study of children with febrile seizures, definite abnormalities on brain MRI were found in 11.4% of children with simple febrile seizures, suggesting that brain abnormalities may lower seizure threshold in febrile children, but none of the imaging findings affected clinical management, hence it did not alter the recommendation that imaging is not indicated [17,18].

CT Head
There is no relevant literature to support the use of CT in the workup of a child with simple febrile seizures.

FDG-PET/CT Brain
There is no relevant literature to support the use of FDG-PET/CT in the workup of a child with simple febrile seizures.

HMPAO SPECT or SPECT/CT Brain
There is no relevant literature to support the use of Tc-99m HMPAO SPECT or SPECT/CT in the workup of a child with simple febrile seizures.

Variant 3: Children 6 months to 5 years of age. Complex febrile seizures. Initial imaging.

Complex febrile seizures account for about a third of all febrile seizures in infants and young children (6 months to 5 years of age). Complex febrile seizures are defined as seizures that last >15 minutes, recur more than once in 24 hours, or are focal [19,20]. Seizures in the setting of fever associated with underlying pathology, such as meningitis, encephalitis, or child abuse may present similarly, but are not considered complex febrile seizures by definition. There is a small increased risk for children with complex febrile seizures to develop epilepsy (ie, subsequent afebrile seizures) later in life, but other than an EEG and evaluation by a neurologist, imaging recommendations are the same as for simple febrile seizures [21].

US Head
There is no relevant literature to support the use of US in the workup of a child with complex febrile seizures.

MRI Head
In one study of children with febrile seizures recurrent within 24 hours, neuroimaging revealed benign findings in 7.4% of patients and did not add significant diagnostic or prognostic information [17]. Compared with children with simple febrile seizures, children with complex febrile seizures were found to be more likely to have an imaging abnormality (14.8% in patients with complex febrile seizures and 11.4% in patients with simple febrile seizures), but these findings did not alter the clinical management. In the absence of other neurological indications such as post ictal focal deficits, neuroimaging in complex febrile seizures is unnecessary [18]. Imaging may be performed in selected patients where complex febrile seizure is part of the differential diagnosis but etiologies such as meningitis, encephalitis, or trauma are being considered clinically as the underlying cause of the seizures [19,22]. MRI may also be indicated in children with febrile status epilepticus (seizure lasting >30 minutes) because increased association with imaging findings have been demonstrated in this patient population [23].

CT Head
CT is usually not indicated in the workup of a child with complex febrile seizures. An analysis of six studies, including a total of 161 children with complex febrile seizures, demonstrated that head CT revealed no findings requiring intervention [22].

FDG-PET/CT Brain
FDG-PET/CT is usually not indicated in the workup of a child with complex febrile seizures.

HMPAO SPECT or SPECT/CT Brain
Tc-99m HMPAO SPECT or SPECT/CT is usually not indicated in the workup of a child with complex febrile seizures.

Variant 4: Children 1 month to 17 years of age. Post-traumatic seizures, not including abusive head trauma. Initial imaging.

Seizures may occur secondary to intracranial trauma with reported incidence ranging from 2.4% in mild traumatic brain injury to 28% to 83% in severe traumatic brain injury [24-26]. Abusive head trauma, presence of subdural hematoma, as well as young age, were identified as independent predictors for the development of post-traumatic seizures in children [24]. This variant will not include imaging of seizures in children with abusive head trauma [27,28]; please see the separate ACR Appropriateness Criteria® topic on "Suspected Physical Abuse-Child" [28] for additional information. Neuroimaging allows detection of treatable pathology associated with intracranial trauma and identifies children at greater risk for seizures [27,29].

US Head

There is no relevant literature to support the use of US in the workup of a child with post-traumatic seizures.

MRI Head

A typical MRI examination is longer compared with CT and may not be suited for an intimal examination in the acute trauma setting. MRI may not be practically feasible compared with CT, depending on the overall clinical status of the child. However, MRI has high sensitivity for detecting intracranial hemorrhage, microhemorrhage, and parenchymal injury. Sequences such as susceptibility-weighted imaging and diffusion-weighted imaging are helpful in identifying patients with diffuse axonal injury [27], that is typically not apparent on CT examinations. At an interval after trauma, MRI can be useful in the evaluation of post-traumatic epilepsy, allowing for better identification and delineation of the sequela of prior traumatic brain injury, including gliosis, and volume loss.

CT Head

If imaging is pursued, CT may be useful in the acute post-traumatic settings especially to identify acute intracranial hemorrhage or mass effect. In a study by Lee and Lui [25], CT identified 100% of the acutely treatable lesions in patients with mild trauma. In this study, although CT results were negative in 53% of patients, 7% of patients had lesions that required urgent surgical intervention.

FDG-PET/CT Brain

There is no relevant literature to support the use of FDG-PET/CT in the acute workup of a child with post-traumatic seizures.

HMPAO SPECT or SPECT/CT Brain

There is no relevant literature to support the use of Tc-99m HMPAO SPECT or SPECT/CT in the acute workup of a child with post-traumatic seizures.

Variant 5: Children 1 month to 17 years of age. Focal seizures, not including abusive head trauma. Initial imaging.

Focal seizures are defined as those with onset, limited to one hemisphere of the brain, and include focal aware seizures (retained awareness) and focal impaired awareness seizures (formerly known as complex partial seizures) [3]. Positive yields from neuroimaging of patients with focal seizures are considerably higher when compared with those from imaging of patients with generalized seizures whose neurologic examination is normal [30,31]. Presence of any focal feature to the seizure was found to be independently associated with clinically relevant abnormalities on neuroimaging [32]. Young et al [33] noted a 50% positivity rate for CT when neurologic findings were focal as compared with 6% positive CT findings in patients without focal features. The frequency of recurrence of focal seizures was found to be up to 94%, which is considerably greater than that for generalized seizures (72%) [34].

Several seizure syndromes (eg, benign rolandic seizures, benign occipital epilepsy with classic EEG findings) are sufficiently characteristic to be diagnosed clinically or through specific EEG patterns and usually do not require imaging. Patients that may benefit from imaging include those who do not have typical clinical or EEG findings.

US Head

There is no relevant literature to support the use of US in the workup of a child with focal seizures.

MRI Head

Seizures can result from multiple intracranial pathologies including developmental abnormalities, hemorrhage, neoplasm, and gliosis. Aprahamian et al [35] found that approximately 4% of children with first-time afebrile seizures and focal manifestations had urgent intracranial pathology, most commonly infarction, hemorrhage, and thrombosis. MRI is more sensitive than CT in detection of brain abnormalities and therefore should be the primary

imaging in children with newly diagnosed seizures [36]. In a study by Jan et al [37], MRI demonstrated focal brain abnormalities in 55% of children with seizures, whereas CT was positive in only 18% of children. In the Aprahamian et al [35] study, 205 of 252 children who had a CT scan for their urgent imaging also had a subsequent MRI. Of these 205 children, 58 (28.2%) had abnormal findings on MRI, 29% of abnormal intracranial findings were not seen on initial CT in children with new-onset afebrile seizures with focal features [35]. In a study by Singh et al [38], MRI detected abnormalities not identified by CT in 47% of children who presented with new-onset status epilepticus. Additionally, MRI is superior to CT in identifying peri-ictal cortical abnormalities that might explain clinical deficits after acute seizure [39]. The epileptogenic lesion may not be detected using routine MRI protocols. Therefore, in these cases, an optimized epilepsy protocol with adequate spatial resolution and multiplanar reformatting is essential. A proper MRI investigation of patients with focal epilepsy requires the use of specific protocols, which are selected based on identification of the region of onset by clinical and EEG findings.

CT Head

A study by Maytal et al [40] suggests a limited role for emergent CT as opposed to scheduled MRI in patients presenting with first-time seizure. In this study, 78.8% of all children who presented to the emergency department with new onset of seizures and underwent CT of the brain demonstrated no imaging findings. For imaging in the setting of abusive head trauma please see the ACR Appropriateness Criteria® topic on "Suspected Physical Abuse-Child" [28].

FDG-PET/CT Brain

There is no relevant literature to support the use of FDG-PET/CT in initial management of focal seizures.

HMPAO SPECT or SPECT/CT Brain

There is no relevant literature to support the use of ictal/interictal Tc-99m HMPAO SPECT or SPECT/CT in initial management of focal seizures.

Variant 6: Children 1 month to 17 years of age. Primary generalized seizure (neurologically normal). Initial imaging.

The term generalized seizure, implies diffuse or generalized involvement of the brain on EEG or clinically [3]. Generalized seizures differ from a focal seizure with secondary generalization (now known as focal to bilateral tonic-clonic), which starts focally and then propagates to both hemispheres [3]. According to the most recent International League Against Epilepsy seizures classification, generalized seizures are categorized as motor and nonmotor (absence) seizures, but for the purpose of a diagnostic imaging workup, it is appropriate to classify them into generalized seizures in an otherwise neurologically normal child and generalized seizures in a neurologically abnormal child [3].

US Head

There is no relevant literature to support the use of US in the workup of a neurologically normal child with generalized seizure.

MRI Head

MRI is rarely indicated in evaluation of a neurologically normal child presenting with generalized seizures because the rate of positive intracranial findings in this group is low, given their genetic underpinnings. MRI is typically not indicated in patients with very typical forms of primary generalized epilepsy (eg, juvenile myoclonic epilepsy, childhood absence) or patients with characteristic clinical and EEG features and patients with adequate response to antiepileptic drugs. Sharma et al [31] studied 500 consecutive emergency department patients presenting with a first afebrile seizure. They defined two clinically significant high-risk indicators of abnormal neuroimaging: 1) presence of predisposing condition, and 2) focal seizure. Only 2% of low-risk patients had abnormal imaging findings on MRI.

CT Head

CT is usually not indicated in the evaluation of an otherwise neurologically normal child with a generalized seizure. The frequency of positive CT findings in patients with idiopathic generalized seizures in children with normal neurologic examination and negative EEG has been estimated to be 2.5% [41,42].

FDG-PET/CT Brain

There is no relevant literature to support the use of FDG-PET/CT in the workup of a neurologically normal child with generalized seizure.

HMPAO SPECT or SPECT/CT Brain
There is no relevant literature to support the use of Tc-99m HMPAO SPECT/CT in the workup of a neurologically normal child with generalized seizure.

Variant 7: Children 1 month to 17 years of age. Generalized seizure (neurologically abnormal). Initial imaging.

Neurological abnormalities associated with generalized seizures may be historical (known from past medical history) such as developmental delay or cerebral palsy, physical abnormalities as in postictal Todd's paralysis, or manifesting as an abnormal sensorium. It is important to note that distinction between generalized and partial seizures can be difficult to make and can evolve in the same patient over time. Reinus et al [43] demonstrated that 100% of patients with seizures and positive CT results had either an abnormal neurologic examination, an abnormal EEG, or a known malignancy. Although Hart et al [34] reported that 83% of patients younger than 16 years of age at the time of initial seizure experienced seizure recurrence, seizures that were associated with a neurologic deficit recurred in 100% of patients.

US Head
There is no relevant literature to support the use of US in the workup of a child with generalized seizure and abnormal neurological findings.

MRI Head
Patients with generalized seizures and abnormal neurologic findings can significantly benefit from MRI. MRI offers higher soft-tissue contrast than CT and provides additional information regarding brain anatomy.

CT Head
CT has a limited role in the evaluation of a child with generalized seizures and abnormal neurological examination. Young et al [33] reported only 6% of CT examinations were positive for generalized seizures in contrast to nearly 50% positivity in focal epilepsy. CT may have an advantage over MRI in only uncommon situations of children with unstable clinical status with generalized seizures and abnormal neurological examination. In these cases, CT may provide initial diagnostic information that helps to guide early therapeutic decisions [44].

FDG-PET/CT Brain
There is no relevant literature to support the use of FDG-PET/CT in the workup of a child with generalized seizure and abnormal neurological findings.

HMPAO SPECT or SPECT/CT Brain
There is no relevant literature to support the use of Tc-99m HMPAO SPECT or SPECT/CT in the workup of a child with generalized seizure and abnormal neurological findings.

Variant 8: Children 1 month to 17 years of age. Intractable seizures or refractory epilepsy.

Refractory seizures 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, and some of these cases are potentially treatable by surgical intervention.

Anatomic imaging with MRI may assist in determining the underlying pathology and help assess anatomical changes associated with seizure activity. Functional imaging, using MRI, PET, or SPECT, may depict seizure foci that are occult by anatomic imaging and may help guide a safe and effective surgical outcome.

US Head
US is not useful in the workup of a child with intractable seizures or refractory epilepsy.

MRI Head
MRI is considered the most sensitive and specific anatomic imaging technique in the evaluation of patients with intractable seizures and should be performed using dedicated epilepsy protocols with 3T scanners whenever possible. This includes, but is not limited to, a T1-weighted volumetric acquisition (3-D) with isotropic voxel size of 1 mm as well as images optimized for the evaluation of hippocampal pathology that include high-resolution thin coronal slices. Studies have shown that in this clinical scenario, MRI has a sensitivity of 84% with specificity of 70%, whereas the sensitivity of CT is approximately 62% [45]. MRI is particularly useful in the evaluation of mesial temporal sclerosis and cortical abnormalities that may be the cause of refractory seizures [46,47]. The data are limited on the additional value of specialized MRI sequences, such as diffusion tensor imaging, which may help to improve specificity in localization of the epileptogenic lesion in cases where conventional structural MRI is

nonlesional [48]. Task-based blood oxygenation level–dependent functional MRI can be useful for presurgical planning, especially for language lateralization [49]. Use of MRI with intravenous (IV) contrast should be reserved for selected cases and specific abnormalities (eg, neoplasm or vascular malformation). In a prospective study of 190 epileptic-operated patients, Lascano et al [45] showed that among all noninvasive imaging modalities, only MRI and high-density electric source imaging (EEG with a high number of electrodes) were independent predictors of favorable postsurgical outcome reaching 92% when these two tests were in concordance.

CT Head

CT has lower sensitivity compared with MRI in localization and characterization of a potential epileptogenic focus. Available data indicate that the diagnostic yield of CT in evaluation of a child presenting with a breakthrough seizure in the setting of known refractory epilepsy is also very low. Allen et al [50] showed that in a cohort of 124 children presenting with breakthrough seizures, almost 17% underwent CT scans and none of them demonstrated acute findings.

FDG-PET/CT Brain

Functional imaging is most utilized for refined evaluation when surgical intervention is contemplated or when structural imaging with MRI is normal or shows nonspecific findings [36]. A study by Leach et al [51] showed that MRI failed to demonstrate findings that would allow guidance for surgery in up to 58% of patients with surgically proven focal cortical dysplasia, supporting the need for a multimodality approach and underscoring the importance of functional studies in preoperative surgical planning. FDG-PET/CT has been shown to improve lesion detection and can be a helpful modality when anatomic imaging (CT and MRI) is normal or in cases when multiple structural abnormalities are present. In a study by Kim et al [52], interictal FDG-PET was shown to have statistically significantly better detection power ($P = .013$) than MRI, with the higher percentage of cases with MRI discordance and PET localization than in reverse. Menon et al [53] showed that approximately 31% of patients with drug-resistant epilepsy were selected for respective surgery based on FDG-PET results. Sensitivity of FDG-PET in localization of an epileptogenic lesion has been shown to be 63% to 67% [45,54,55]. At the same time, specificity of FDG-PET in localization-related epilepsy with nonlesional MRI reaches 94% [45,55]. There are limited data that show FDG-PET as having prognostic value regarding the outcome of epilepsy surgery in refractory focal epilepsy [56]. In a cohort of patients with temporal lobe epilepsy, surgical outcomes for PET-positive and MRI-negative patients did not differ from outcomes of patients with mesial temporal sclerosis demonstrated on MRI [57]. FDG-PET has been shown to be useful in evaluating residual foci of seizure activity in patients who have undergone unsuccessful surgical intervention [58]. More recently, FDG-PET and MRI coregistration has also been shown to improve lesion detection. This can be performed by fusion of the PET images with separately acquired MRI or as single-setting PET, not MRI acquisition [59,60].

HMPAO SPECT or SPECT/CT Brain

SPECT or SPECT/CT using either Tc-99m HMPAO or Tc-99m-ECD (ethyl cysteinate dimer) can be a helpful localizing tool for intractable epilepsy when anatomic imaging (CT and MRI) is normal [52] or when multiple structural abnormalities are present, and it has been shown to be effective even in infants when cerebral hemodynamic responses are immature [61]. Ictal SPECT is useful in differentiating temporal lobe epilepsy from extratemporal lobe epileptogenic foci and provides noninvasive imaging information used in treatment-planning strategies. Studies have compared FDG-PET and ictal subtraction SPECT and demonstrated that, overall, SPECT had higher sensitivity (49%–87%) than FDG-PET (56%–63%) but also that these two tests proved to be complementary with FDG-PET, providing additional information in 33% of cases in which SPECT did not demonstrate the seizure focus [45,62]. 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 [63]. Ictal SPECT/CT hyperperfusion adds predictive value to anatomic imaging and EEG as an 86% frequency of favorable postsurgical outcome was shown after complete removal of the SPECT/CT hyperperfusion zone in comparison with the 75% frequency of seizure freedom after removal of the MRI-EEG–defined epileptogenic region [64]. Subtraction ictal SPECT coregistered to MRI has increased the sensitivity of this modality up to 67% [54]. Concordance between the results of ictal SPECT and FDG-PET was shown to be a predictive factor for surgical outcomes in extratemporal epilepsies [65]. Both SPECT and FDG-PET have been used in some centers as part of presurgical evaluation and planning strategy.

Summary of Recommendations

- **Variant 1**: MRI head without IV contrast is usually appropriate for the initial imaging of neonatal seizures.
- **Variant 2**: Imaging is usually not appropriate for the assessment of simple febrile seizures in children 6 months to 5 years of age.
- **Variant 3**: MRI head without IV contrast may be appropriate for the initial imaging of children 6 months to 5 years of age with complex febrile seizures.
- **Variant 4**: CT head without IV contrast or MRI head without IV contrast is usually appropriate for the initial imaging of children with post-traumatic seizures (not including abusive head trauma). These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 5**: MRI head without IV contrast is usually appropriate for the initial imaging of a child with focal seizures (not including abusive head trauma). The panel did not agree on recommending MRI head without and with IV contrast for this clinical scenario. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure in this clinical setting. Imaging in this patient population is controversial but may be appropriate.
- **Variant 6**: MRI head without IV contrast may be appropriate for the initial imaging of children with primary generalized seizure (neurologically normal).
- **Variant 7**: MRI head without IV contrast is usually appropriate for the initial imaging of children with generalized seizure (neurologically abnormal).
- **Variant 8**: MRI head without IV contrast is usually appropriate for children with intractable seizures or refractory epilepsy. The panel did not agree on recommending MRI head without and with IV contrast for children with intractable seizures or refractory epilepsy. There is insufficient medical literature to conclude whether or not these patients would benefit from administration of IV gadolinium contrast in this clinical setting.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

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

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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 [66].

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 "Varies."		

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