1. Imaging Parameters:
	1. Epilepsy-specific Protocol: *(Check only one)* [ ]  Yes [ ]  No
	2. Contrast used: [ ]  Yes [ ]  No
	3. Magnetic Field Strength of Scanner Used: [ ]  1.5T [ ]  3.0T [ ] 7.0T [ ]  Other, specify:
	4. Date Scan Performed: mm dd yyyy
2. Imaging Normality: *(Check only one)*

[ ]  Normal

[ ]  Abnormal

* 1. If Abnormal, number of abnormality types:
	2. If Abnormal, describe abnormality type(s):

1 = Hippocampal sclerosis (HS)

2 = Malformation of cortical development (MCD)

3 = Vascular

4 = Neoplasm

5 = Inflammatory/infectious

6 = Atrophy or tissue loss

7 = Tumor-like lesion (e.g., epidermoid and dermoid)

[ ]  Incidental (not relevant for epilepsy evaluation)

[ ]  Other / indeterminant class (includes amongst others: incomplete hippocampal inversion/malrotation, MNVT, focal region of white or grey matter signal abnormality of uncertain diagnosis): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Location:

Table for Locations - Cortical

| **Table for Locations - Cortical** |
| --- |
| Cortical (Check all that apply) | Side (Check only one) | Abnormality type identification number(s) | Contrast enhancing? |
| [ ]  Dorsal lateral frontal (DLF)  | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Frontal Polar (FP) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Mesial frontal (MF) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Orbital frontal (OF) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Dorsal lateral parietal (DLP) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Mesial parietal (MP) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Basal occipital (BO) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Lateral occipital (LO) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Mesial occipital (MO) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Basal temporal (BT) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Lateral temporal (LT) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Mesial temporal (MT) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Temporal polar (TP) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Insula (INS) | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |

| Table for Locations - Subcortical |
| --- |
| Subcortical (Check all that apply) | Side (Check only one) | Abnormality type identification number(s) | Contrast enhancing? |
| [ ]  Basal ganglia | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Callosum | [ ]  N/A |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Grey-white matter junction | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Periventricular | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  Thalamus | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |
| [ ]  White matter-other | [ ]  Left [ ]  Right [ ]  Bilateral |  | [ ]  Yes [ ]  No [ ]  N/A |

1. **Features:**

**Table for Features**

| Features (Check all that apply) | Abnormality type identification number(s) |
| --- | --- |
| [ ]  Agenesis |  |
| [ ]  Atrophy |  |
| [ ]  Cortical thinning |  |
| [ ]  Cystic (including multicystic) |  |
| [ ]  Decreased grey-white matter distinction |  |
| [ ]  Dysgenesis (includes dysmorphology of cortical mantle) |  |
| [ ]  Heterotopic tissue versus migration abnormality |  |
| [ ]  Encecphalocele(s) |  |
| [ ]  Hypertrophy |  |
| [ ]  Hyperplasia (grey or white matter) |  |
| [ ]  Hypoplasia (grey or white matter) |  |
| [ ]  Loss of architecture (specific to hippocampus) |  |
| [ ]  Malformation related white matter signal abnormality |  |
| [ ]  Resection |  |

1. Impression of Specific Abnormalities(Check all that apply):

|  |  |  |  |
| --- | --- | --- | --- |
| Specific Abnormalities(Check all that apply): | Side (Check only one) | Distribution | Contrast enhancing? |
| 5a. 1 = Hippocampal sclerosis (HS)If applicable, specify:[ ]  HS only[ ]  HS plus temporal dysplasia/atrophy[ ]  Remote lesion/pathology plus HS, dual pathology[ ]  Other, specify: | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |
| 5b. 2 = Malformation of cortical development (MCD) If applicable, specify:[ ]  Band heterotopias[ ]  Development tumor-like lesion[ ]  Focal cortical dysplasia (not transmantle FCD)Transmantle focal cortical dysplasia/bottom-of-sulcus dysplasia (BOSD)[ ]  Hemimegalencephaly[ ]  Heterotopia / heterotopion not periventricular nodular heterotopia[ ]  Hypothalamic hamartoma[ ]  Lissencephaly[ ]  Microcephaly[ ]  Pachygyria[ ]  Macrocepahally[ ]  Partial Hemimegalencephaly[ ]  Periventricular nodular heterotopia[ ]  Polymicrogyria[ ]  Schizencephaly (malformation related only)[ ]  Transmantle focal cortical dysplasia[ ]  Tuberous sclerosis[ ]  Other, specify: | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |
| 5c.3 = VascularIf applicable, specify:[ ]  Arterial stroke[ ]  Arterial vascular malformation[ ]  Cavernoma[ ]  Hemorrhage (including post hemorrhage evidence, e.g., periventricular)[ ]  Venous stroke[ ]  Vascular malformation, Other specify: | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |
| 5d.4 =Neoplasm (If Developmental tumor-like lesion, see MCD to classify)If applicable, specify:[ ]  Primary[ ]  Secondary | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |
| 5e. 5 = Inflammatory / infectiousIf applicable, specify:[ ]  Abcess[ ]  Cysticercosis[ ]  Encephalitis, Other, specify:[ ]  Limbic encephalitis[ ]  Sarcoidosis[ ]  Vasculitis | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |
| 5f. 6 = Atrophy or tissue lossIf applicable, specify: (check all that apply)[ ]  Encephalomalacia (related to surgery, abscess, radiation, trauma)[ ]  Vascular related (If caused by Stroke, see Vascular to classify) | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multilobar[ ]  Hemispheric[ ]  Multifocal[ ]  Diffuse / generalized | [ ]  Yes [ ]  No [ ]  N/A |

|  |  |  |  |
| --- | --- | --- | --- |
| Specific Abnormalities(Check all that apply): | Side (Check only one) | Distribution | Contrast enhancing? |
| 5g.7 =Tumor-like lesion (e.g., epidermoid and dermoid lesion)  | [ ]  Left [ ]  Right[ ]  Bilateral | [ ]  Unifocal[ ]  Multifocal | [ ]  Yes [ ]  No [ ]  N/A |

## GENERAL INSTRUCTIONS

Provided below are the minimum requirements for MRI epilepsy evaluation to evaluate cause for seizures and confirm or direct investigations to the seizure focus. They are directed at identifying the most common causes of focal epilepsy: Malformations of cortical development, hippocampal sclerosis (HS), tumor, vascular, and inflammatory causes. As malformations of cortical development are the most common causes of epilepsy in children emphasis should be on a combination of T1, T2, and FLAIR images; Images are optimally obtained on 3T scanners, and for T1 and FLAIR isotropic voxels ≤ 1 mm.

If the 1st MRI scan is performed between ages 8 and 18 months is normal, then the MRI study should be repeated at age 24-30 months if seizures persist (the cerebral cortex is difficult to evaluate in children imaged 8-18 months due to on-going myelination and relatively poor of contrast between cortex and white matter).

General sequences are listed, but not specific imaging parameters as they depend on make of scanner and magnetic field strength. Suggestions are provided for adult, children and infants (< 2 years age).

In addition to these basic imaging protocols, consideration should be given to:

* Axial magnetization transfer T1 weighted images in children <14 y.o.
* High resolution coronal turbo/fast spin echo T2 weighted images of the hippocampal formations (orthogonal to the long axis), 2 mm skip 0.
* Contrast need not be routinely used unless characterization of vascular, tumor or inflammatory lesion is considered necessary.
* Perfusion, diffusion sequences are optional.
* Turbo / fast spin echo proton density sequences (4-5 mm thick) can be useful in detection of subtle transmantle dysplasias.

## Adults (14 and older)

* Axial turbo / fast spin echo T2-weighted images (2 mm skip 0), whole brain
* Coronal turbo / fast spin echo T2 weighted high resolution coronal oblique sequence (512 x 512, maximum slice thickness of 2 mm), whole brain
* FLAIR, Multislice or 3D
* Sagittal 3D T1 weighted gradient echo volume sequence (256 x 256, maximum slice thickness of 1.0 mm for isotropic voxels). Sagittal preferred, coronal acceptable, axial is not advised. The quality of this sequence is critical since it is relied upon for post-processing–reformatting for evaluation of cortical thickness, image registration and segmentation, including volumetry.
* Standard sagittal T1-weighted sequence images (if gradient echo volume sequence is not acquired in the sagittal plane)

All coronal sequences should be acquired in an oblique plane orthogonal to the long axis of the hippocampus.

## Children for 2-14 years:

* Axial turbo / fast spin echo T2-weighted images (2 mm skip 0), whole brain
* Coronal turbo / fast spin echo T2 weighted high resolution coronal oblique sequence (512 x 512, maximum slice thickness of 2 mm), whole brain
* FLAIR, Multislice or 3D
* Sagittal T1 weighted gradient echo volume sequence (256 x 256, maximum slice thickness of 1.0 mm for isotropic voxels. Sagittal preferred, coronal acceptable, axial is not advised. The quality of this sequence is critical since it is relied upon for post-processing– reformatting for evaluation of cortical thickness, image registration and segmentation, including volumetry.
* Standard sagittal T1-weighted sequence images (if gradient echo volume sequence is not acquired in the sagittal plane)

All coronal sequences should be acquired in an oblique plane orthogonal to the long axis of the hippocampus.

## Infants (< two years)

* Children younger than two years require special sequences as immature myelination affects the ability to identify common causes of epilepsy. MR imaging (especially high resolution T2 images) performed early in the first year of life in infants with epilepsy is important to identify areas of cortical or subcortical dysplasia.
* Axial turbo / fast spin echo T2-weighted images (2 mm skip 0), whole brain
* Coronal turbo / fast spin echo T2 weighted high resolution coronal oblique sequence (512 x 512, maximum slice thickness of 2 mm), whole brain
* Sagittal turbo / fast spin echo T2-weighted images (2 mm skip 0), whole brain
* Standard sagittal T1-weighted sequence images (if gradient echo volume sequence is not acquired in the sagittal plane)
* Volumetric 3D T1 weighted sequences are less useful prior to age one year due to incomplete myelination on T1 sequences
* FLAIR, Multislice or 3D weighted

## Specific Instructions

“Only one number is given per abnormality. Pick the one that is most applicable.” The lesion number should be included in the ‘Abnormality identification number(s)’ column of the Location and Features tables, respectively.

Abnormal types

1 = Hippocampal sclerosis (HS)

Hippocampal sclerosis is the commonest cause of drug-resistant epilepsy in adults and is associated with alterations to structures and networks beyond the hippocampus. In addition to being a cause of epilepsy, the hippocampus is vulnerable to damage from seizure activity. (Walker, 2015) HS is particularly associated with the syndrome of mesial temporal lobe epilepsy (MTLE) but can be seen at post-mortem in other epilepsy syndromes. (Thom, 2014)

2 = Malformation of cortical development (MCD)

Malformations of cortical development (MCD) is a condition where the cortex sequence is altered during the formation of the brain. MCDs are an important cause of epilepsy (Barkovich et al., 2015) and are common causes of medically refractory epilepsy, particularly in children. (Barkovich et al., 2012)

3 = Vascular

Intracranial vascular malformations (IVMs) encompass a spectrum of blood vessel abnormalities are clinically important because they may cause epileptic seizures and/or hemorrhage. IVMs may be classified as arteriovenous malformations (AVMs) and cerebral cavernous malformations (CCMs). AVMs and CCMs are the IVMs mainly responsible for epileptic seizures. (Josephson et al., 2015)

4 = Neoplasm

Seizures are common in patients with brain tumors. Epilepsy can result from various types of brain tumors, such as glioneuronal tumors, high grade gliomas, meningiomas and metastases, but is most common in patients with low grade intrinsic lesions (aka low-grade gliomas). (Englot et al, 2016) Urbach (2013) describes the epidemiology, clinical presentation, pathology and imaging for the epilepsy associated tumors: gangliogliomas, dysembryoplastic neuroepithelial tumor (DNET), angiocentric glioma, pilocytic astrocytoma, pleomorphic xanthoastrocytoma, and diffuse gliomas.

5 = Inflammatory/infectious

Epileptic seizures resulting from infections of the CNS (viral, bacterial, fungal and parasitic infectious diseases, inflammation due to non-infectious inflammation that occurs after insults to the brain or neuroinflammation due to encephalitis and other autoimmune diseases. (Husari & Dubey, 2019;Vezzani et al., 2011;Vezzani et al., 2016)

6 = Atrophy or tissue loss

Brain atrophy, the loss of neurons (brain cells) and associated decreased brain volume can lead to temporal lobe epilepsy and idiopathic generalized epilepsy. (Larivière et al., 2020)

7 = Tumor-like lesion (e.g., epidermoid and dermoid)

Epidermoids: developmental lesions without dermal appendages, 10-15% of which are found in a parasellar, middle cranial fossa location, where they tend to cause temporal lobe seizures.

Dermoids: developmental lesions that are rarer than epidermoids cause headaches and seizures (20% of cases). Males present with these symptom more than females.

Dysembryoplastic neuroepithelial tumor (DNET): a low-grade, slow-growing brain tumor. It is a glioneuronal tumor, which contains properties of both glial and neuronal cells. In children and adolescents, DNETs of the brain present with seizures almost 100 % of the time. (Ranger et al., 2015)

Encepalocele: An encephalocele is a sac-like protrusion or projection of the brain and the membranes that cover it through an opening in the skull. Encephalocele happens when the neural tube does not close completely during pregnancy.

Multinodular and vacuolating neuronal tumor (MVNT): a rare benign brain lesion, commonly found in middle-aged adults. Patients experience a range of symptoms from being asymptomatic to epileptic seizures, with headache being the most common symptom. (Arbuiso et al., 2021)

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