Neuroimaging in Diagnosis of Epilepsy

선우준상
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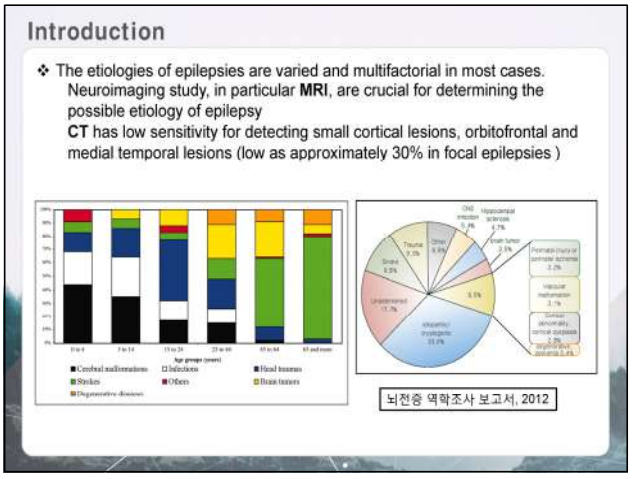
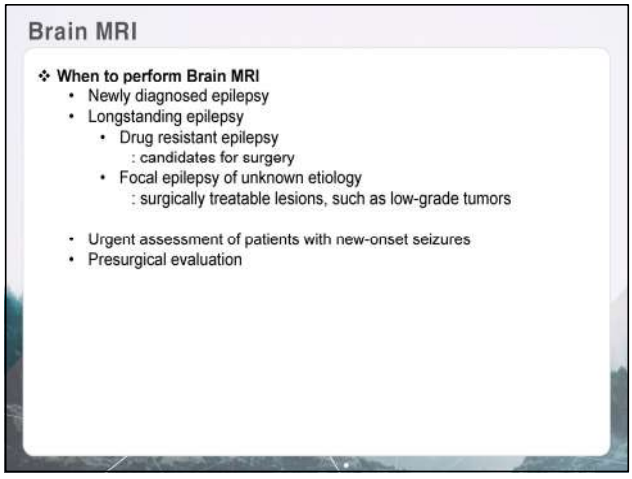
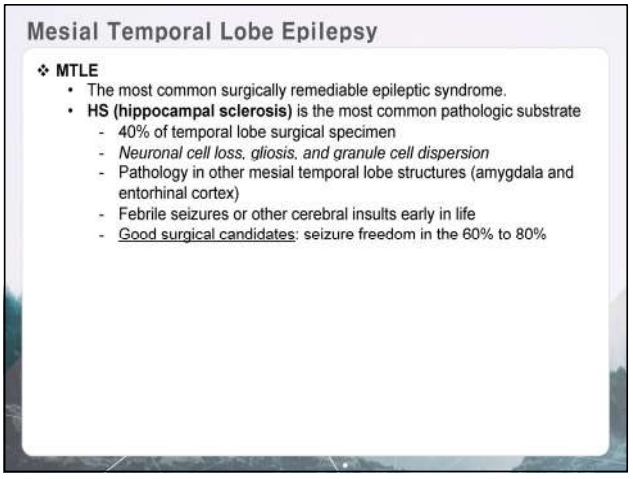
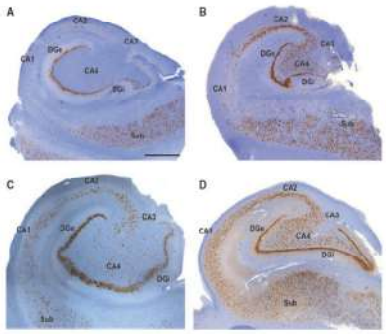






Histopathologic subtypes of HS



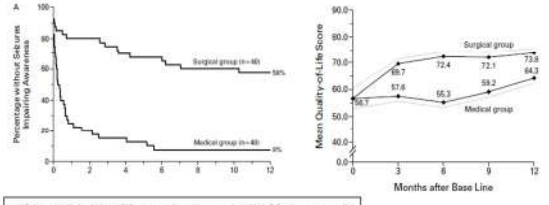
A. ILAE HS type 1
B. ILAE HS type 2
C. ILAE HS type 3
D. No HS

NeuN immunohistochemistry with hematoxylin counterstaining

Epilepsia, 54(7):1315–1329, 2013

Temporal lobe resection

A RANDOMIZED, CONTROLLED TRIAL OF SURGERY FOR TEMPORAL-LOBE EPILEPSY



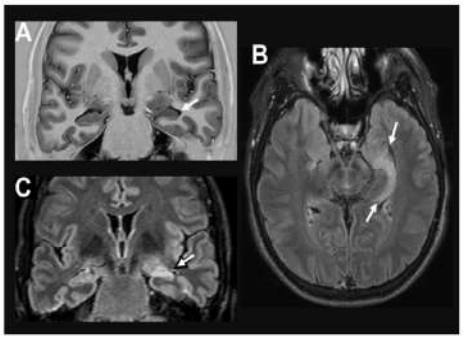
HS in MRI: 72.5% (medical) and 70.0% (surgical)

N Engl J Med. 2001;345(5): 311-318

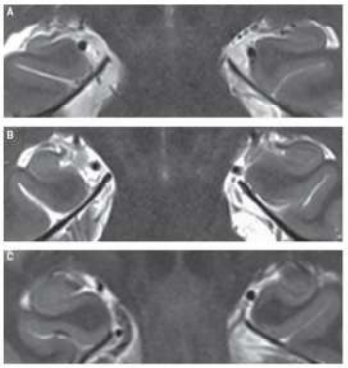
MRI findings of HS

- **Hippocampal atrophy**
  The most specific and reliable feature
  Determined by comparing the size on each side on **coronal** slices (small asymmetries can be normally present)
  Shape of the hippocampus: oval (normal) → **flattened** (HS)
- **Increased T2/FLAIR signal**
  May be insufficient to diagnose HS in isolation
- **Loss of internal hippocampal structure**
  Consequence of neuronal loss and gliosis
- **Other features**
  Asymmetry of the temporal horn of the lateral ventricles
  Atrophy of the anterior temporal lobe
  Atrophy of the fornix and mammillary body

MRI findings of HS



MRI findings of HS



Degrees of hippocampal atrophy

A. ILAE HS type 1: severe
B. ILAE HS type 2: moderate
C. ILAE HS type 3: not detectable

Epilepsia, 54(7):1315–1329, 2013

Neocortical epilepsy

- The most common lesions causing neocortical epilepsies:
  Low-grade tumors, malformations of cortical development, posttraumatic and postischemic lesions, inflammatory infectious scars, cavernous malformations, and arteriovenous malformations

Focal cortical dysplasia

❖ **FCD**

Approximately one-fourth of focal epilepsies
Highly epileptogenic, leading to intractable epilepsy in 75%
Characterized by disorganization of the cortical lamination associated with bizarre (dysplastic) neurons or balloon cells
General MRI findings

- cortical thickening
- loss of the interface between white and gray matter
- focal atrophy
- hyperintense signal in T2/FLAIR sequences

FCD classification

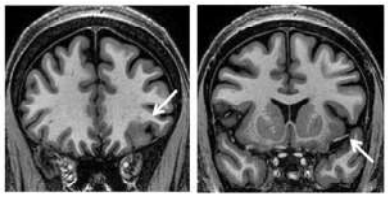
Table 1. The three-tiered ILAE classification system of focal cortical dysplasia (FCD) distinguishes isolated forms (FCD Types I and II) from those associated with another principal lesion (FCD Type III).

FCD Type I (isolated)	Focal cortical dysplasia with abnormal radial cortical lamination (FCD Type Ia)	Focal cortical dysplasia with abnormal tangential cortical lamination (FCD Type Ib)	Focal cortical dysplasia with abnormal radial and tangential cortical lamination (FCD Type Ic)
FCD Type II (isolated)	Focal cortical dysplasia with dysmorphic neurons (FCD Type IIa)		Focal cortical dysplasia with dysmorphic neurons and balloon cells (FCD Type IIb)
FCD Type III (associated with principal lesion)	Cortical lamination abnormalities in the temporal lobe associated with hippocampal sclerosis (FCD Type IIIa)	Cortical lamination abnormalities adjacent to a glial or glioneuronal tumor (FCD Type IIIb)	Cortical lamination abnormalities adjacent to vascular malformation (FCD Type IIIc)	Cortical lamination abnormalities adjacent to any other lesion acquired during early life, e.g., trauma, ischemic injury, encephalitis (FCD Type IIId)

FCD Type III (not otherwise specified, NOS): if clinically/radiologically suspected principal lesion is not available for microscopic inspection.
Please note that the rare association between FCD Types IIa and IIb with hippocampal sclerosis, tumors, or vascular malformations should not be classified as FCD Type III variant.

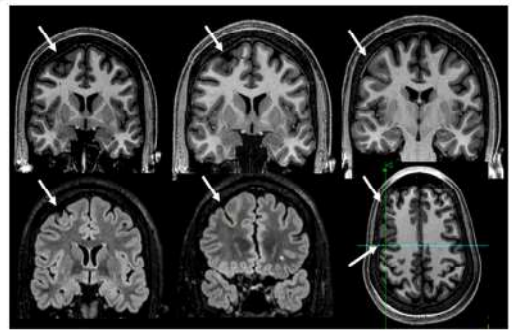
Epilepsia, 52(1):158–174, 2011

FCD type I



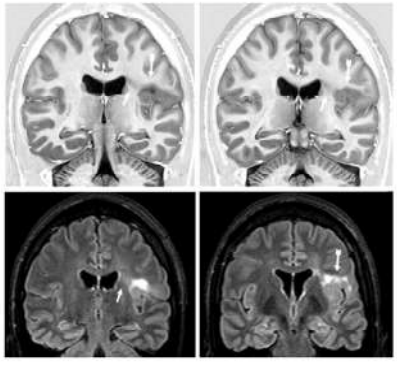
Thickened cortex and **blurred cortical-subcortical transition** in the left lateral-basal frontal lobe.
Also be associated with focal volume loss and thin cortex
In many patients MRI does not show abnormalities in the white matter

FCD type II



Thickened cortex associated with abnormal gyri and cortical dimple (T1)
slightly blurred cortical-subcortical transition (FLAIR)
Pathology: **FCD Type IIA**

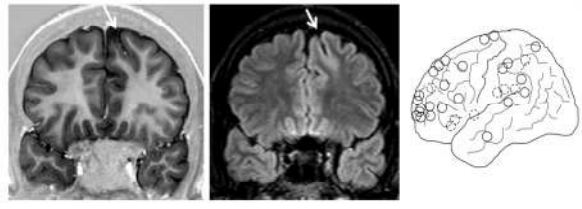
FCD type II



FCD Type IIB

Cortical thickening
Loss of the cortical-subcortical transition
"Transmantle" sign
hyperintense T2 FLAIR signal in the subcortical white matter with a wedge shape that extends to the ventricle

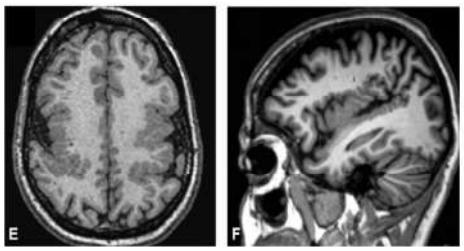
FCD type II



FCD Type IIB
"Bottom-of-sulcus" dysplasia
Thickened cortex and hyperintense FLAIR signal in the bottom of deep sulcus
Dysplastic features are **maximal at the sulcal depth**, tapering to a **relatively normal gyral crown**, with or without transmantle sign
The most common location: frontal, parietal, and insula cortex
Motor/premotor/ prefrontal seizure semiology, the nocturnal occurrence
Surgically remediable (seizure free rate: 88%, 28/32)

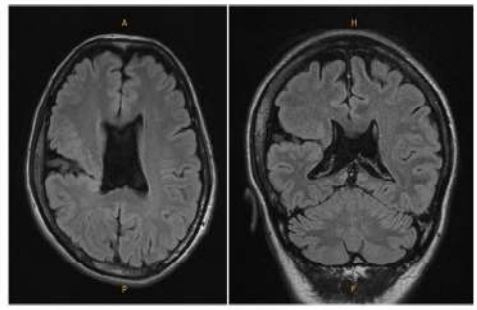
Neurology 2015;84:2021–2028

Polymicrogyria



Excessive small and prominent convolutions separated by shallow sulci with focal cortical thickening
Predilection for the perisylvian region

Schizencephaly



Cleft that connects the cortical surface with the ventricular lumen
Cortical tissue of at the edges is usually abnormal (polymicrogyria)

Epilepsy-associated tumors

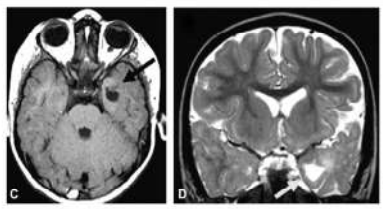
Table 1 Neuropathological findings in epilepsy surgery

Category	Numbers (%)	Age OP	Onset	Duration
HS	1,908 (32.7 %)	33.9 + 10.4	11.3 + 7.7	22.7 + 10.0
Dual	294 (5.0 %)	25.5 + 12.8	9.5 + 7.8	15.9 + 9.9
LEAT	1,551 (26.5 %)	27.9 + 12.3	16.5 + 10.1	11.8 + 8.8
MCD	930 (15.9 %)	18.2 + 12.0	5.9 + 5.7	12.3 + 9.1
Vascular	328 (5.6 %)	36.1 + 12.3	23.4 + 11.4	12.7 + 9.0
Glial scars	284 (4.9 %)	25.6 + 12.4	10.3 + 8.0	14.7 + 8.6
Encephalitis	96 (1.6 %)	20.4 + 12.6	13.3 + 9.4	8.2 + 7.1
No lesion	451 (7.7 %)	29.2 + 10.8	12.6 + 7.7	16.1 + 8.0
Total	5,842	28.6 + 12.5	12.4 + 8.9	16.5 + 10.1

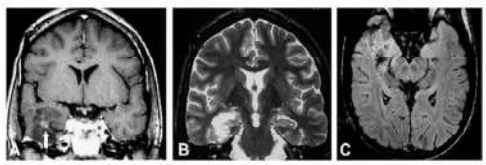
❖ **LEAT** (long-term epilepsy-associated tumors, epileptoma)
Every fourth patient submitted to epilepsy surgery
Spectrum of **low-grade glial** and **glio-neuronal** phenotypes
Slow growth and low risk for malignant progression
Gangliogliomas (GG) and Dysembryoplastic neuroepithelial tumor (DNTs): two most common (65%)
Temporal lobe (77%)
Can be associated with FCD (ILAE Type IIIb)

Acta Neuropathol (2014) 128:39–54

Epilepsy-associated tumors

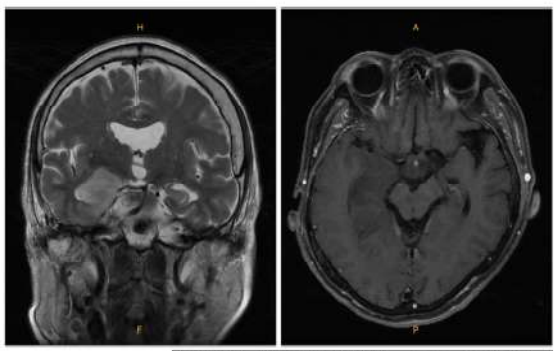


Ganglioglioma



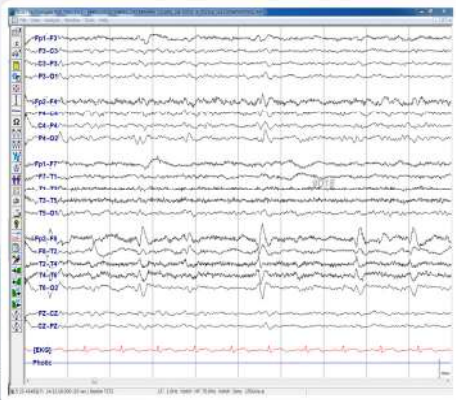
DNET

Epilepsy-associated tumors

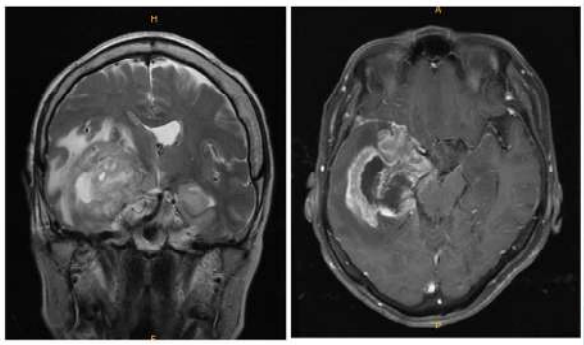


73세 여자. 내원 1일 전 발생한 confusion으로 내원
CSF profile: normal

Epilepsy-associated tumors



Epilepsy-associated tumors



Presurgical Evaluation

Presurgical evaluation of epilepsy

❖ **Objective of resective epilepsy surgery**

Complete resection or complete disconnection of the ***epileptogenic zone***, which is defined as the area of cortex indispensable for the generation of clinical seizures.

Table 1 *Descriptions of zones and lesions of the cortex (adapted from Lüders and Awad, 1992)*

Epileptogenic zone	Region of cortex that can generate epileptic seizures. By definition, total removal or disconnection of the epileptogenic zone is necessary and sufficient for seizure-freedom
Irritative zone	Region of cortex that generates interictal epileptiform discharges in the EEG or MEG
Seizure onset zone	Region where the clinical seizures originate
Epileptogenic lesion	Structural lesion that is causally related to the epilepsy
Ictal symptomatogenic zone	Region of cortex that generates the initial seizure symptoms
Functional deficit zone	Region of cortex that in the interictal period is functionally abnormal, as indicated by neurological examination, neuropsychological testing and functional imaging or non-epileptiform EEG or MEG abnormalities
Eloquent cortex	Region of cortex that is indispensable for defined cortical functions

Brain. 2001;124(Pt 9):1683-700.

Lesional and Non-lesional epilepsy

❖ **Lesional epilepsy**

Epilepsy with an unequivocal MRI abnormality responsible for seizures
2.5-times greater likelihood of a seizure-free outcome

Categories (n of studies)	Non-lesional			Lesional		
	Total N patients	Seizure-free %	95%CI	Total N patients	Seizure-free %	95%CI
Temporal and extratemporal						
Overall (n=35)	697	43	39–46	2860	68	66–70
Using MRI (n=19)	398	46	41–51	965	70	68–73
Using histopathology (n=17)	302	39	34–44	1953	67	65–69
Temporal lobe						
Overall (n=20)	398	45	40–49	1657	69	66–70
Using MRI (n=12)	226	51	45–57	514	75	71–89
Using histopathology (n=8)	172	36	29–43	1179	65	63–68
Extratemporal						
Overall (n=13)	156	34	27–41	350	66	61–70
Using MRI (n=9)	124	35	27–42	225	60	54–66
Using histopathology (n=4)	35	32	18–47	125	74	67–82

Similar outcomes in children, adults, and studies that used MRI or histopathology to identify lesions.

Epilepsy Research (2010) 89, 310—318

Lesional and Non-lesional epilepsy

❖ Non-lesional epilepsy

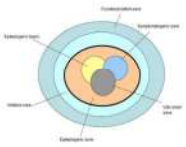
Location	No. of Patients	Engel Class I	II	III	IV
Frontal	35	15	1	12	7
Neocortical temporal	31	17	3	5	6
Parietal	11	3	1	3	4
Occipital	11	7	1	3	0
Multifocal	1	0	0	0	1
Total	89	42 (47.2%)	6 (6.7%)	23 (25.8%)	18 (20.2%)

Localization by FDG-PET and interictal EEG was correlated with a seizure-free outcome

Concordance with two or more presurgical evaluations was significantly related to a **seizure-free outcome**

Surgical treatment can benefit **selected patients** with nonlesional neocortical epilepsy

Careful interpretation of presurgical evaluations and the presence of concordant results

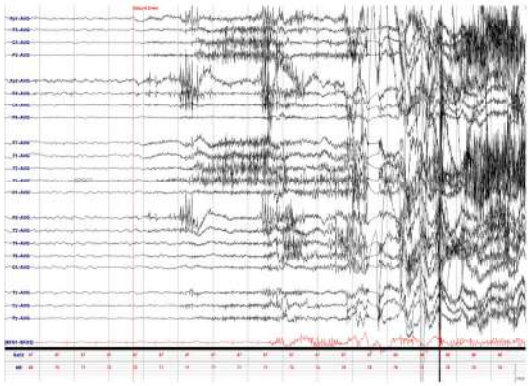


Ann Neurol 2005;58:525–532

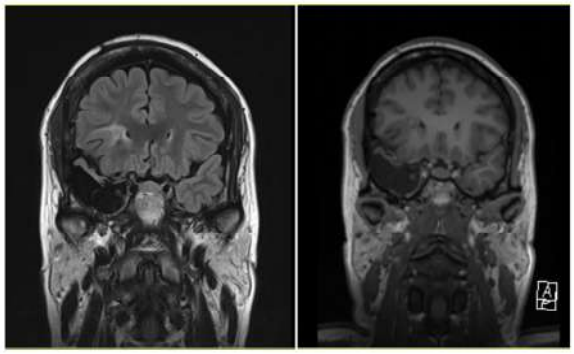
Brief history

여자 33세.
중 2때부터 Sz 시작.
2004년 Rt anterior temporal lobectomy 타병원
수술 이후에도 증상 반복, 2014년부터 빈도 증가 (한 달에 2-3회)
CBM2S 200mg bid, TPRM25 bid 복용

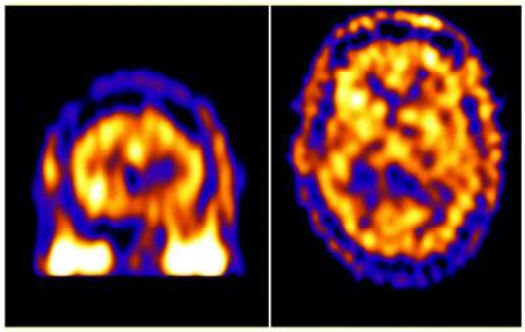
Ictal EEG



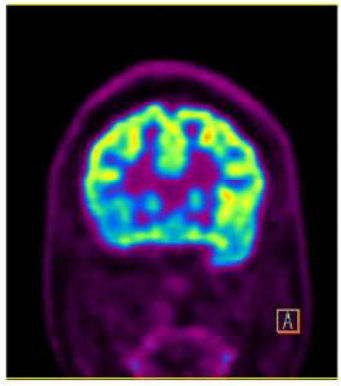
Brain MRI



Ictal SPECT



FDG-PET

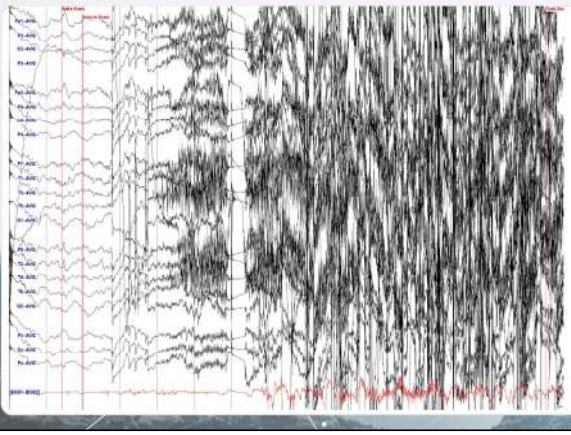


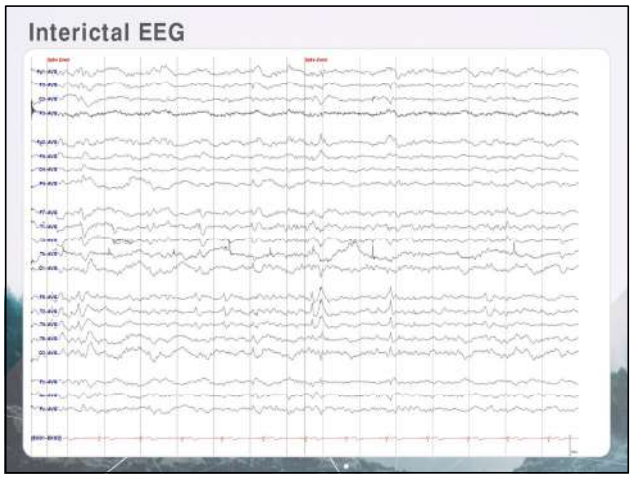
Brief history

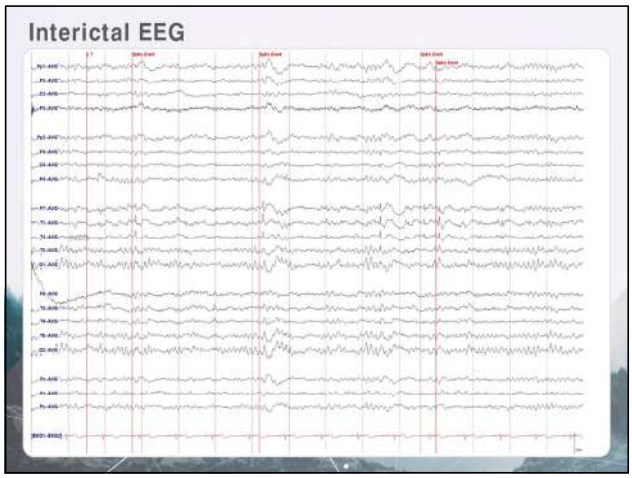
41세 남자
중학교 1학년부터 GTC 양상의 seizure 발생. 여러 대학병원에서 AED 복용했으나 seizure 지속되어 내원.

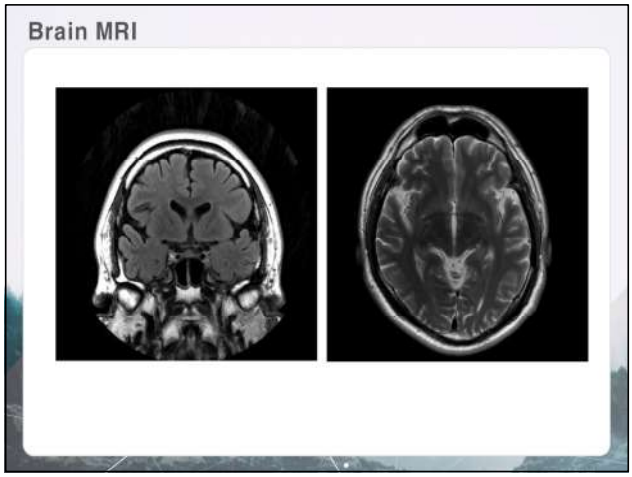
Semiology
- 주로 수면 중에 팔다리 경직되면서 뻗치는 양상으로 발생
- EBD(+), drooling (+), urinary incontinence (-); 매번 일정하지 않다.
- Frequency: variable, 많을 때는 하루 4-5번, 적을 때는 일주일 이상 sz free
- Duration: 30초-1분 미만
- Aura (+): 소름 끼치는 느낌이 아래에서 부터 위로 올라오는 느낌

Ictal EEG

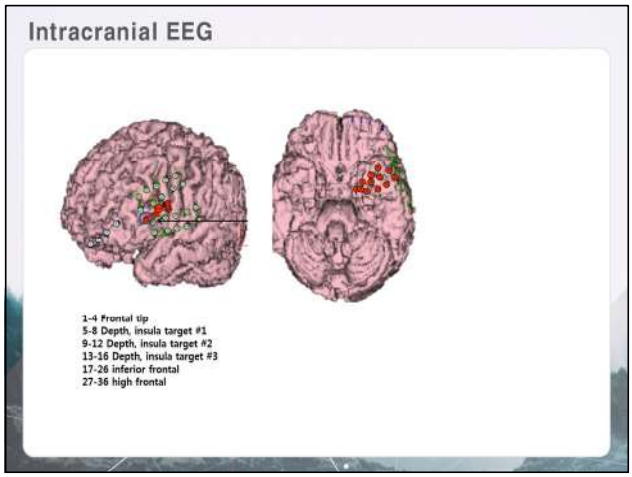


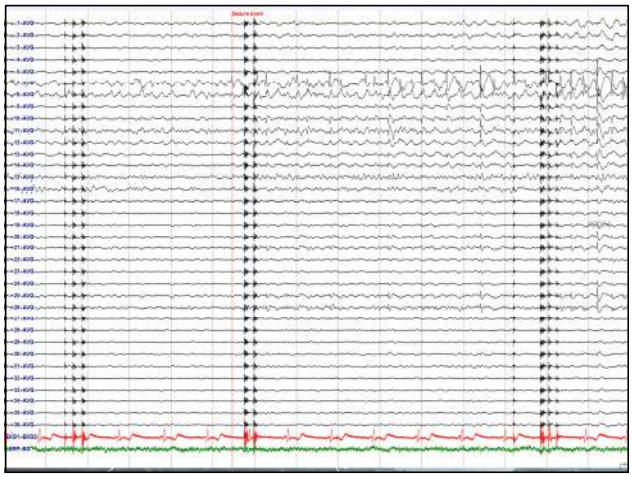

Interictal EEG

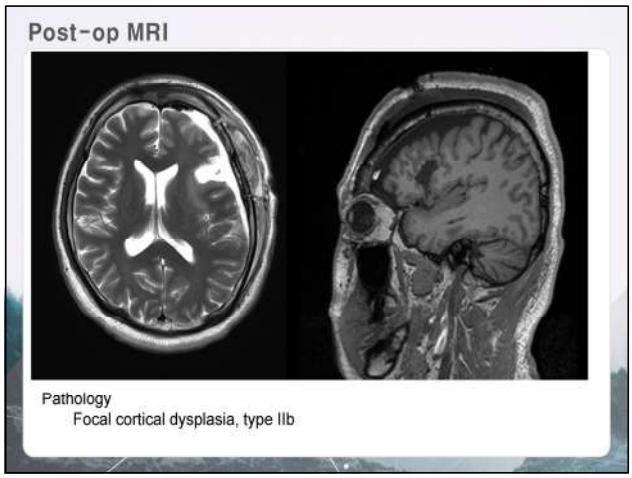

Interictal EEG


Brain MRI


Ictal SPECT


Intracranial EEG
1-4 Frontal slp
5-8 Depth, insula target #1
9-12 Depth, insula target #2
13-16 Depth, insula target #3
17-26 inferior frontal
27-36 high frontal




Post-op MRI
Pathology
Focal cortical dysplasia, type IIb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