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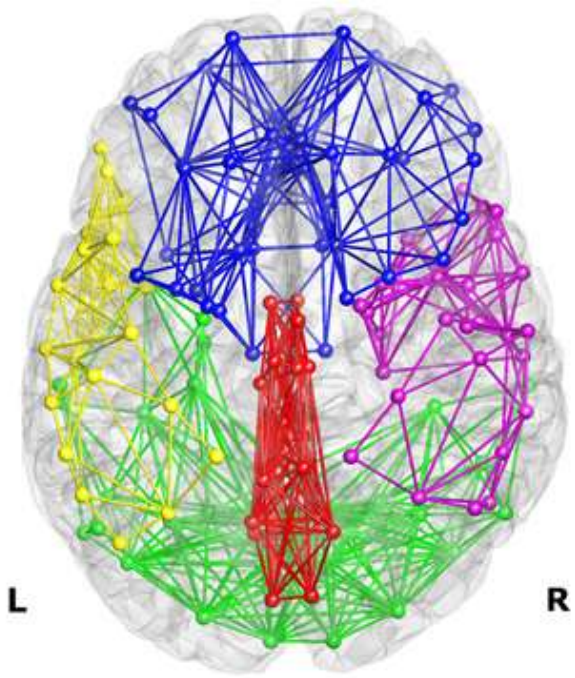
คณะแพทยศาสตร์
ศิริราชพยาบาล



Defining Epileptic Network by seizure semiology and EEG finding

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พ.ท.พญ. ภิรดี สุวรรณภักดี

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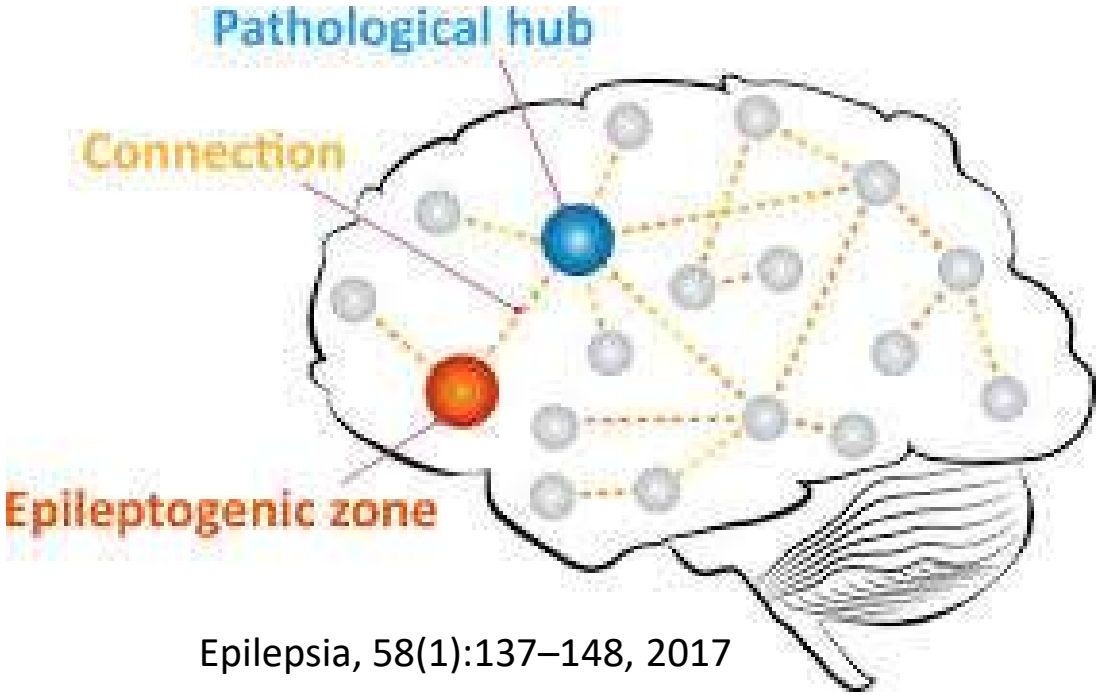
What is Epileptic Network?

- the brain regions → production and propagation of epileptic activities.



Epilepsia, 58(1):137–148, 2017

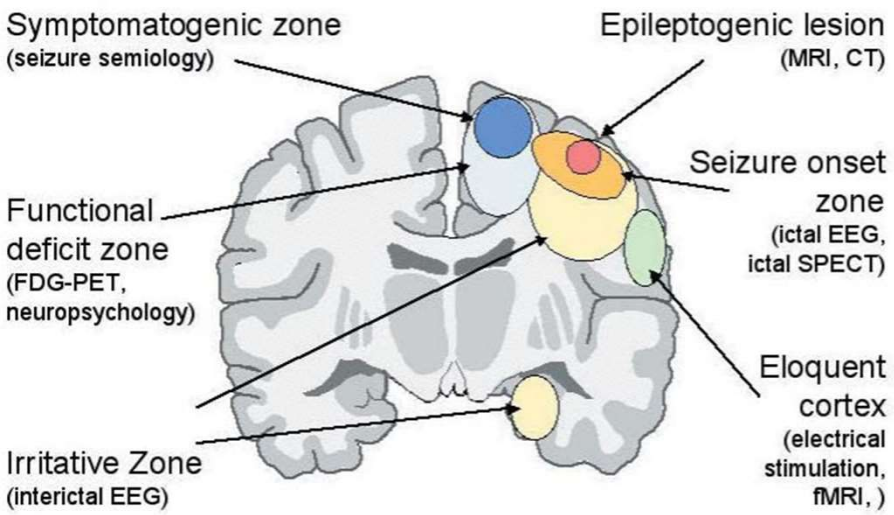
Structural connection

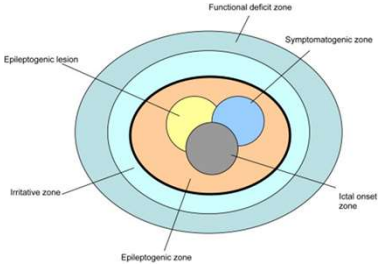
Functional connection

Epileptogenic zone (EZ)

- EZ **cannot** be directly defined by any test but can be estimated by a number of other zones.

1. Symptomatogenic zone
2. Irritative zone
3. Ictal onset zone
4. Epileptogenic lesion
5. Functional deficit zone



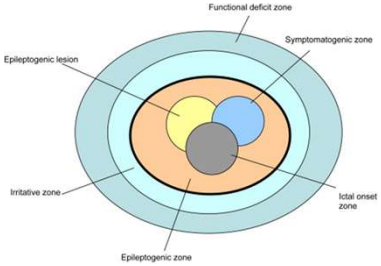


Symptomatogenic zone

- Cortex or regions produce the seizure manifestations.
- Tools: **History taking** and **Video EEG monitoring**
- Lateralization >> Localization

- **Caveat**
  - Not focus only motor signs, but also focus on AURA

- **Limitation**
  - Not all the cortex leading to ictal semiology
  - The earliest detected sign may consider as spreading

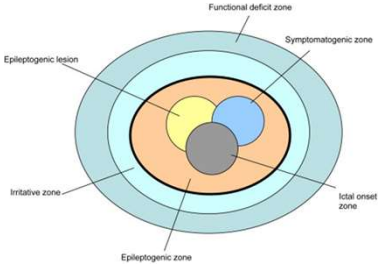


Irritative zone

- Zone that generates **interictal epileptiform d/c.**
- Tools: **EEG, MEG**
- Usually localized within the epileptogenic zone.

Limitation

- in some cases → multiple irritative zones, but might be only 1 of corresponding to the epileptogenic zone.



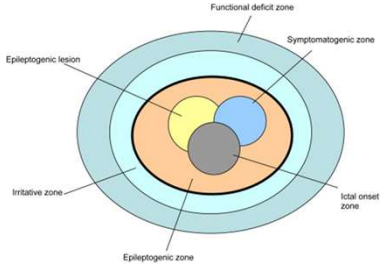
Ictal onset zone

- Area of cortex that is generating seizures.
- Tools: **EEG; noninvasive, invasive, ictal SPECT**
- This zone, if accurately defined, is contained within the epileptogenic zone.

Limitation

- Even the earliest detected ictal activity may be spreading area.

- Even with Intracranial EEG recording, the ictal onset zone may be missed unless the electrodes placed directly over that zone.

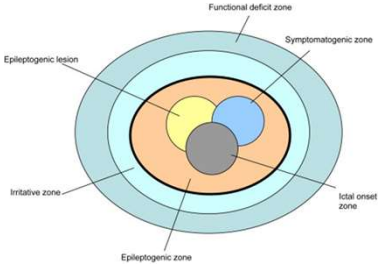


Epileptogenic lesion

- **Structural lesion on CT or MRI** → (presumed) to be the cause of the epilepsy.
- Epileptogenic lesion vs EZ
- **EZ - within the lesion**
  - cortical dysplasia or hypothalamic hamartoma.
- **EZ - from brain surrounding**
  - cavernous malformations and benign tumors.

Limitation

- Certain lesions may not related to the epilepsy. eg. Arachnoid cysts and venous malformations.
- Multifocal lesions, Huge lesion
- Non-lesional MRI



Functional Deficit Zone

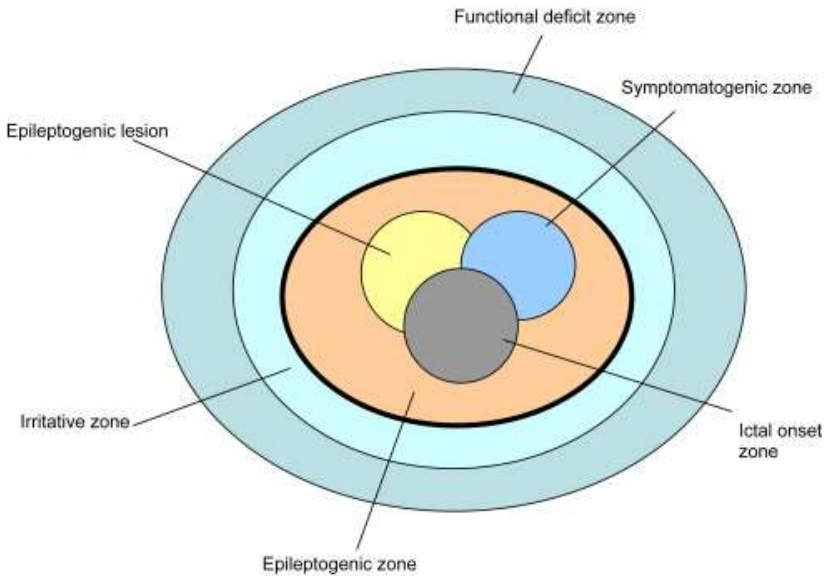
- Responsible for functional deficits.
- Tools:
  - **Neurological examination**
  - **Neuropsychological testing**
  - **Interictal EEG focal slow activity**
  - **Local glucose uptake by PET**
  - **Local cerebral blood flow by interictal SPECT.**
- While the functional deficit zone may include the epileptogenic zone, it is often considerably larger.

Presurgical Evaluation

- History and Physical Exam
- Video EEG monitoring
  - Noninvasive, invasive
- Imaging
  - MRI
  - Functional MRI: PET , SPECT
- Neuropsychology Evaluation
- Comprehensive Patient Care Conference

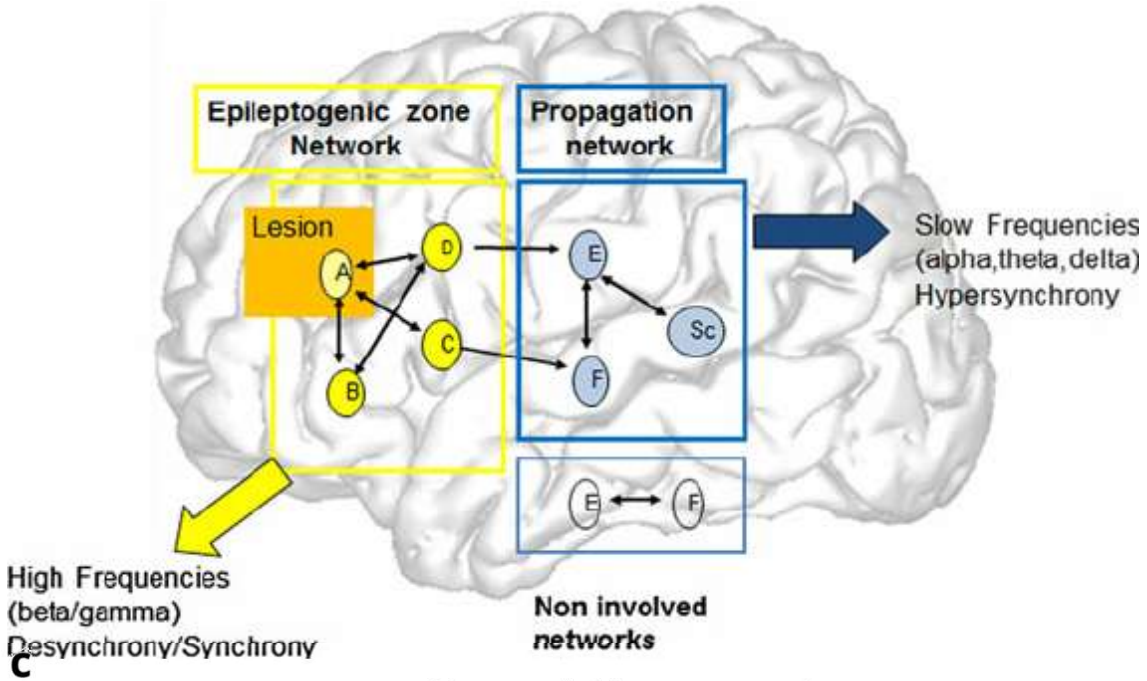
Presurgical work-up is time and labor-intensive and has cost implications.

EEG & VIDEO-EEG MONITORING



- The interictal focal attenuation and focal slow activity - **Functional deficit zone**
- Interictal epileptiform discharges – **Irritative zones**
- EEG localization of seizure onset - **ictal onset zone**
- Seizure semiology – **symptomatogenic zone**

Dynamic network changes



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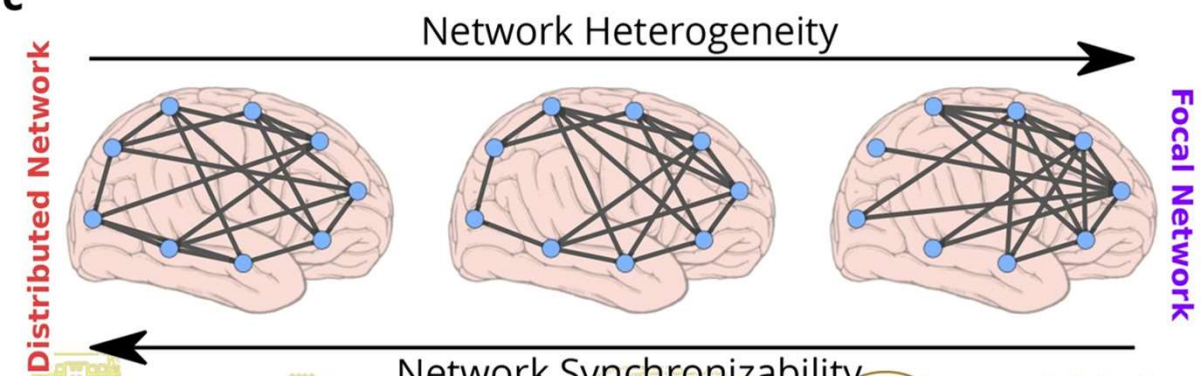


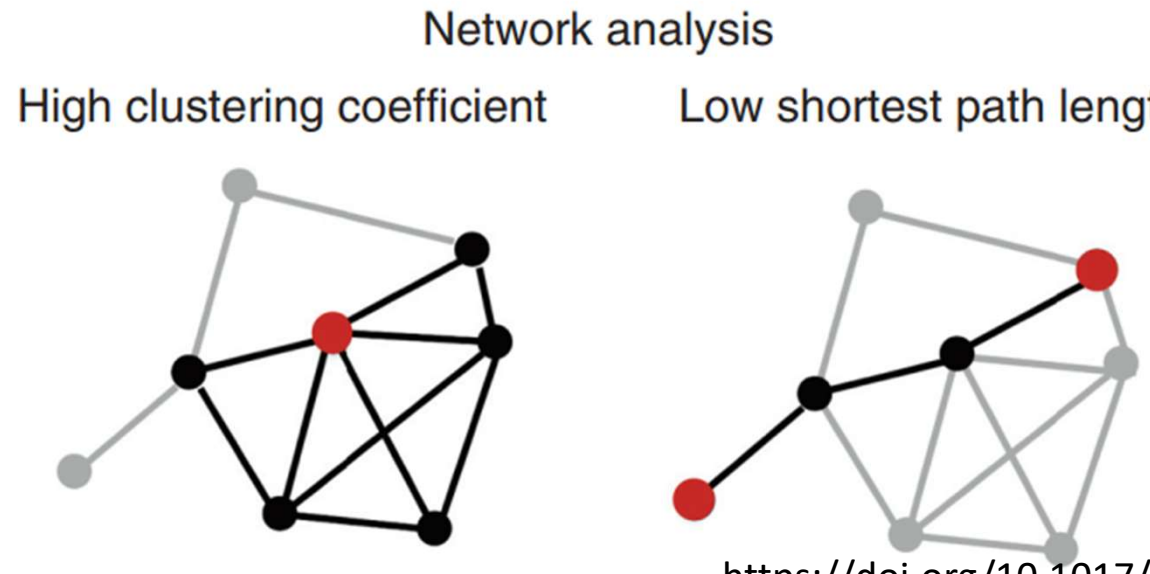
Interictal: Network measuring

Clustering coefficient

- counts the number of connected triangular nodes in a network

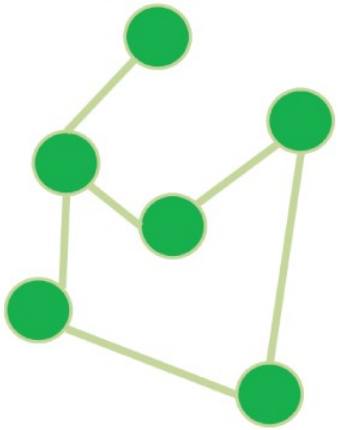
Shortage path length

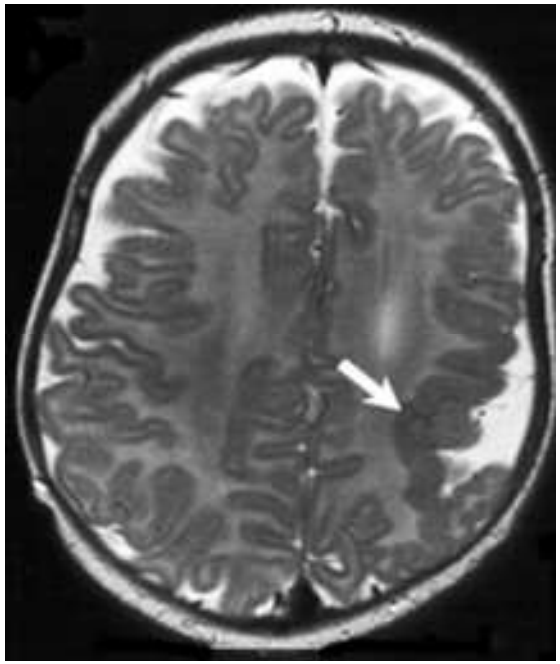
- counts the minimum number of links that connect two nodes



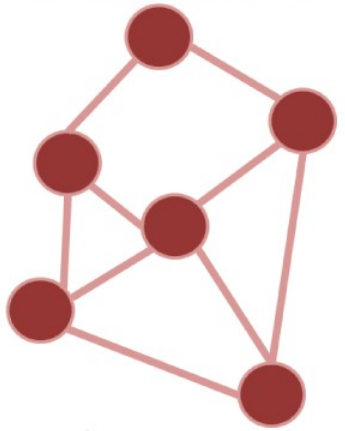
https://doi.org/10.1017/9781316257951.011

Healthy Network

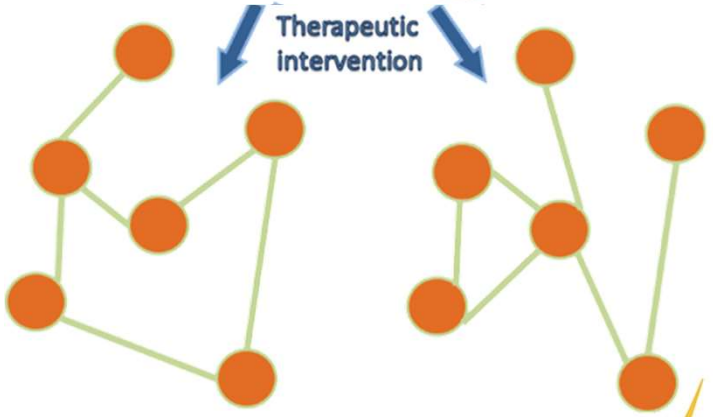




Diseased Network



Therapeutic intervention



Est. 1888

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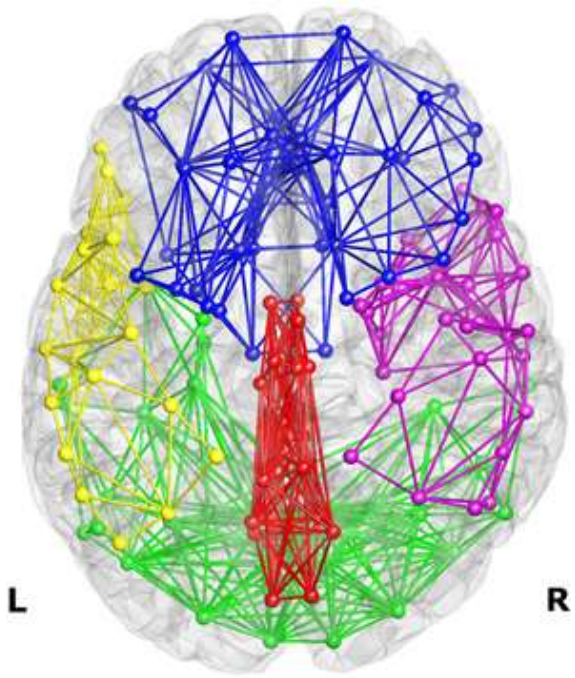

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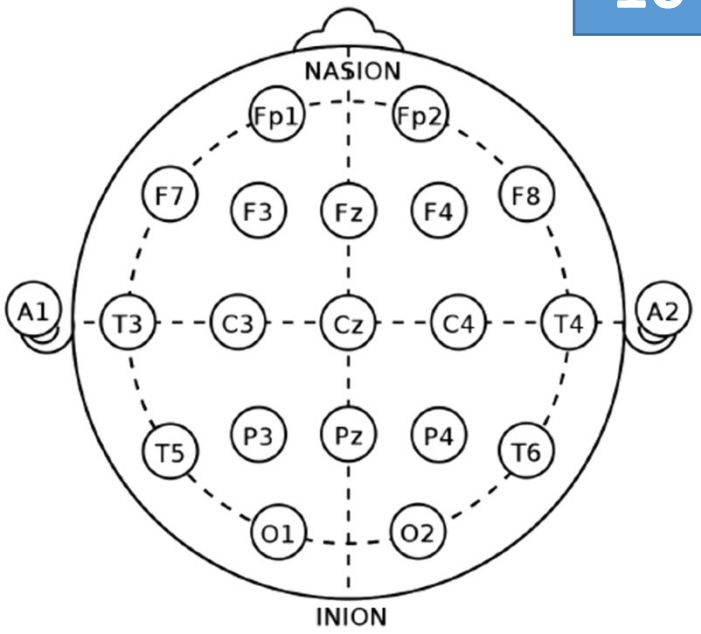
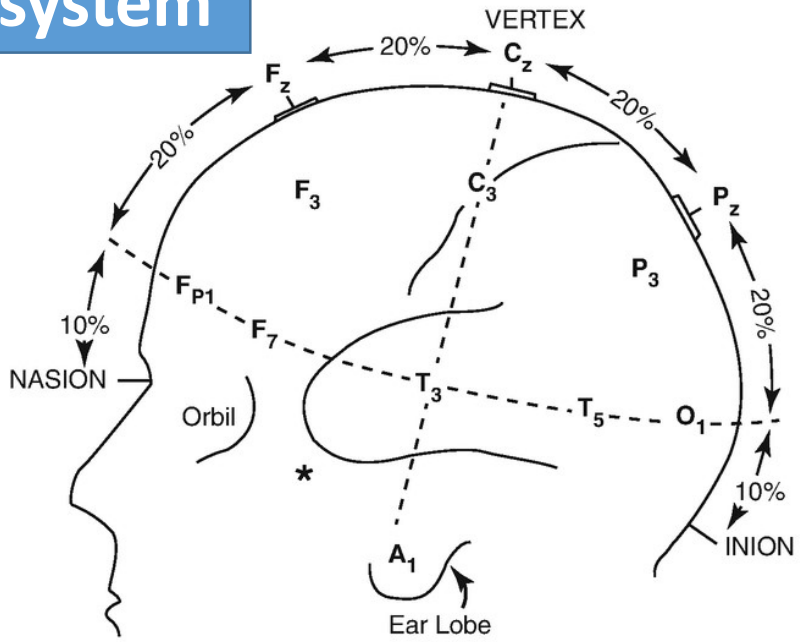
Video EEG monitoring

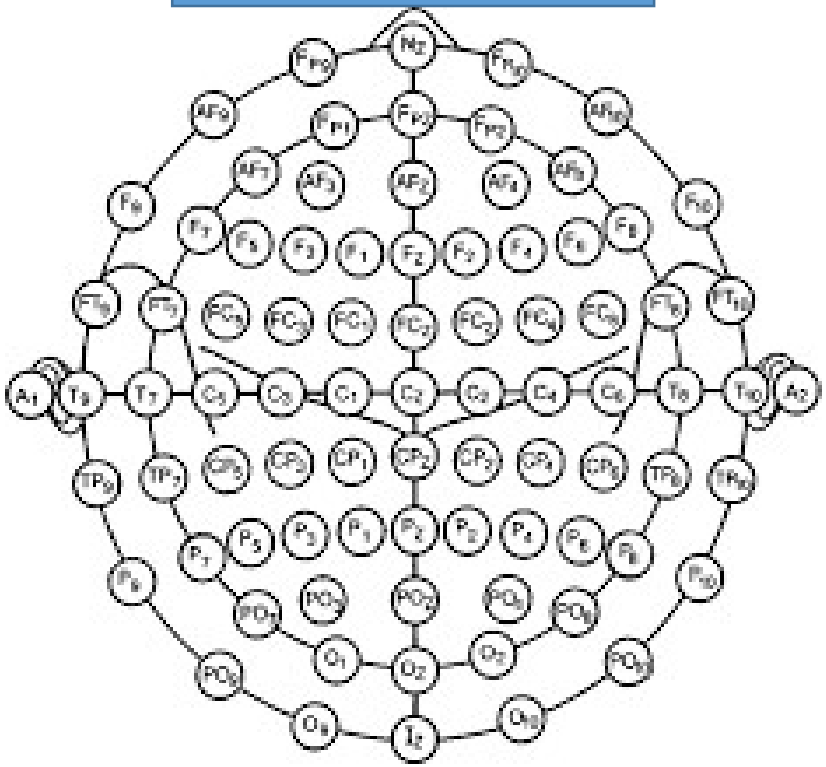
10-20 system



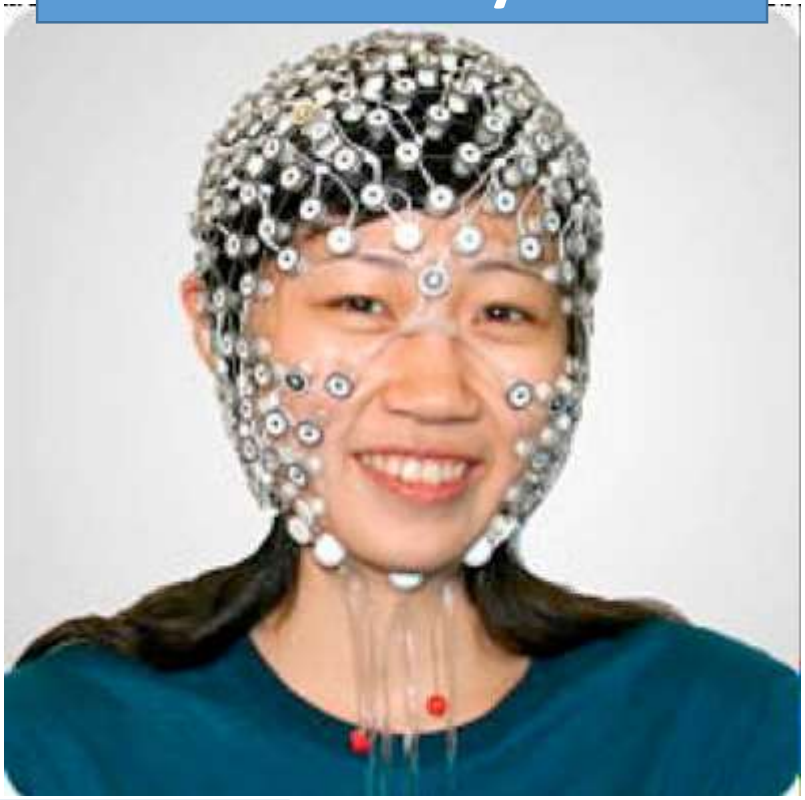


Scalp EEG

10-10 system



Dense-array EEG

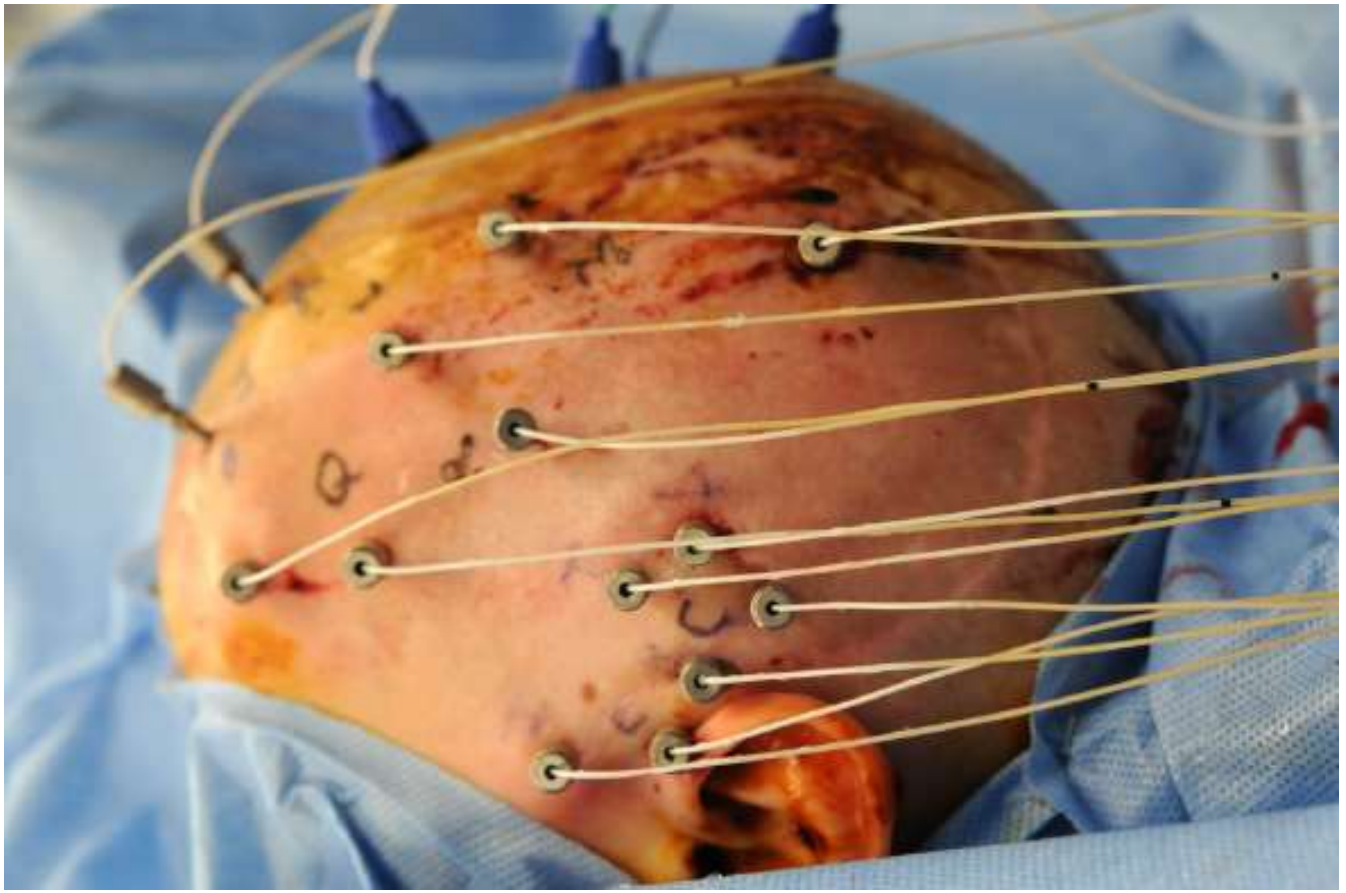


Scalp EEG

Invasive EEG

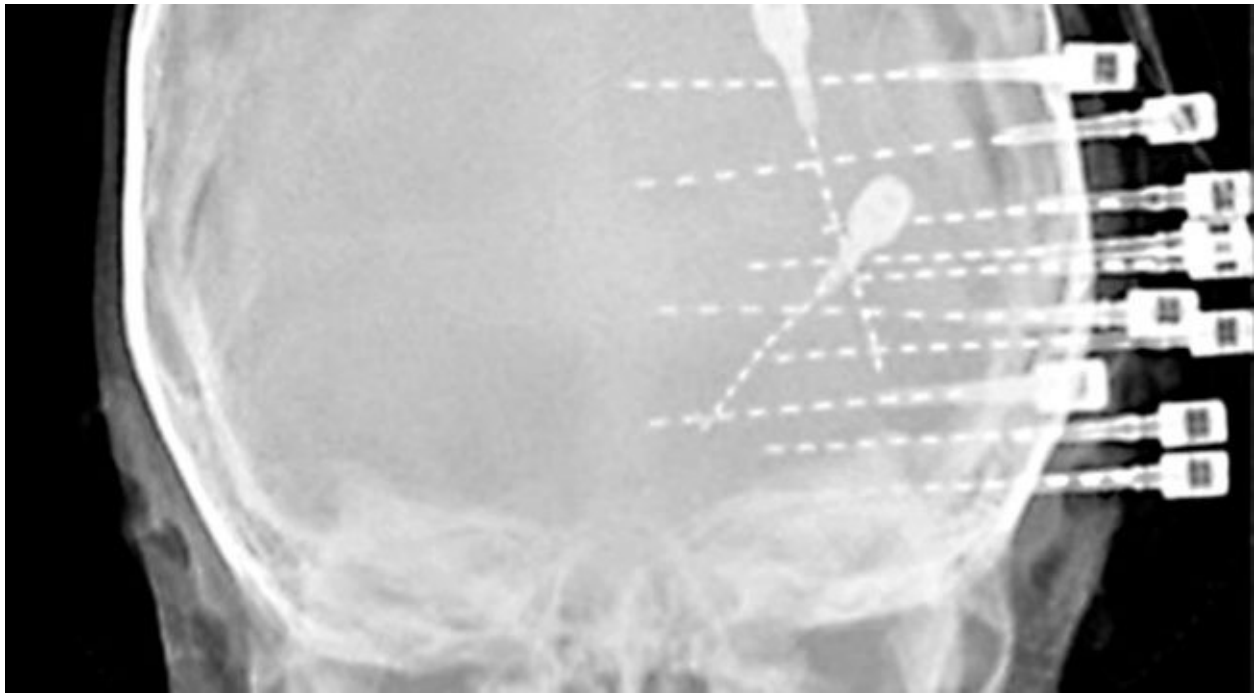
Subdural EEG

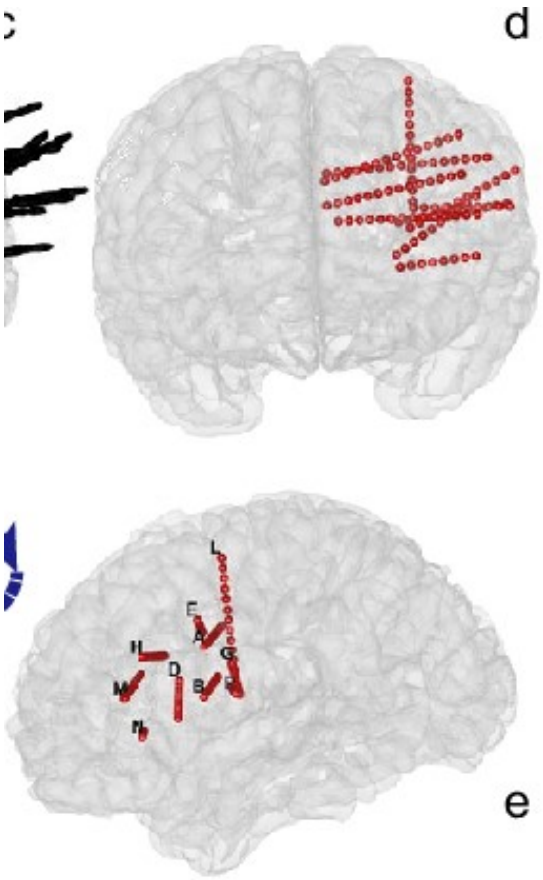
Invasive EEG



Stereo EEG

Invasive EEG





Stereo EEG

How is EEG able to define the epileptic networks?

- Interictal epileptiform discharge
- Ictal EEG
  - Seizure semiology
  - Ictal EEG onset and evolutional pattern
- Cortical stimulation
- Cortico-cortical evoke potential (CCEP)


Case examples

30-year-old right-handed Thai female

Seizure began at 1 year of age;

First SZ

- ขณะอายุ 1ปี มีอาการชักหลังจากมีไข้ 39-40▫C การชักเป็นแบบ GTC SZs ได้รับการวินิจฉัย febrile seizure มีอาการชักสัมพันธ์กับไข้ทุกครั้ง 1-2 ครั้ง/เดือน ไม่มียากันชัก
- จนอายุ 7ปี เริ่มชักโดยไม่มีไข้ ลักษณะชักเปลี่ยนไปเป็นลักษณะดังต่อไปนี้

Seizure description

- Aura (50% of SZs): headache, dizziness , sometimes epigastric pain
- Right hand stiff → staring → whole body tense up + lip smacking for 5 min followed by post ictal confusion for 4-5 min.
- Frequency: >10 times/month

Cephalic/abdominal aura → right hand tonic? → GT SZs?

Seizure Risk Factors

- History of febrile seizures
- No family history of epilepsy syndrome
- Normal birth

Previous Evaluation

- EEG:None
- MRI brain (14/11/60)

  : increase SI and atrophic change of Lt. hippocampus and medial temporal lobe

- WADA test (14/12/60)
  - ❖Language dominant on the Lt. side
  - ❖Memory:
    - Rt. hemisphere injection memory 77%
    - Lt. hemisphere injection memory 0%

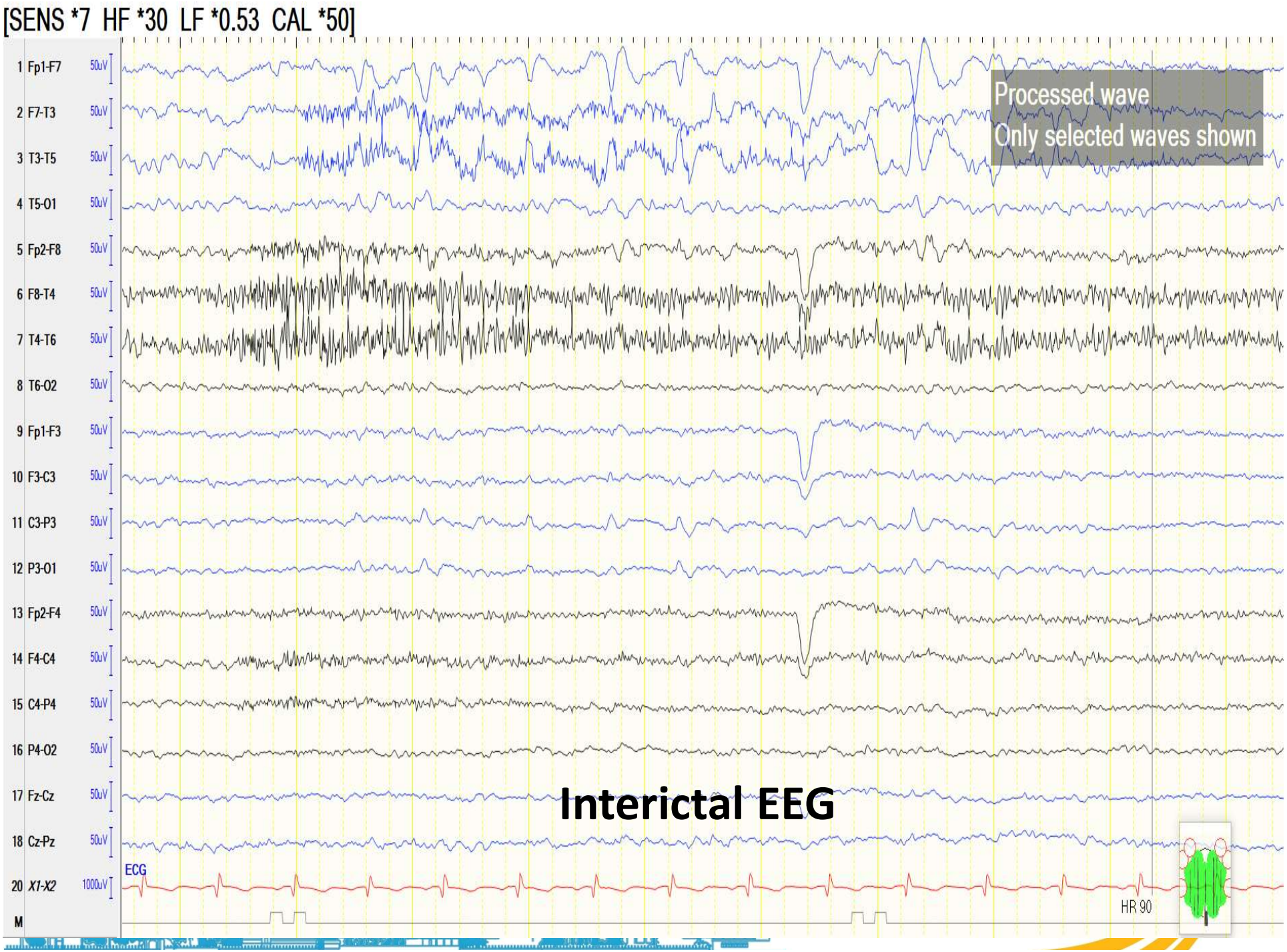
Anti convulsants

- Current AEDs
  - Levetiracetam (500) 3*2pc
  - Na Valproate (500) 1*2pc
  - Phenobarbital (60) 2*1 hs

- Previous tried AEDs and side effects:
  - Carbamazepine (MP rash)

Physical Exam

- Slow respond
- Normal language
- No focal neurological deficit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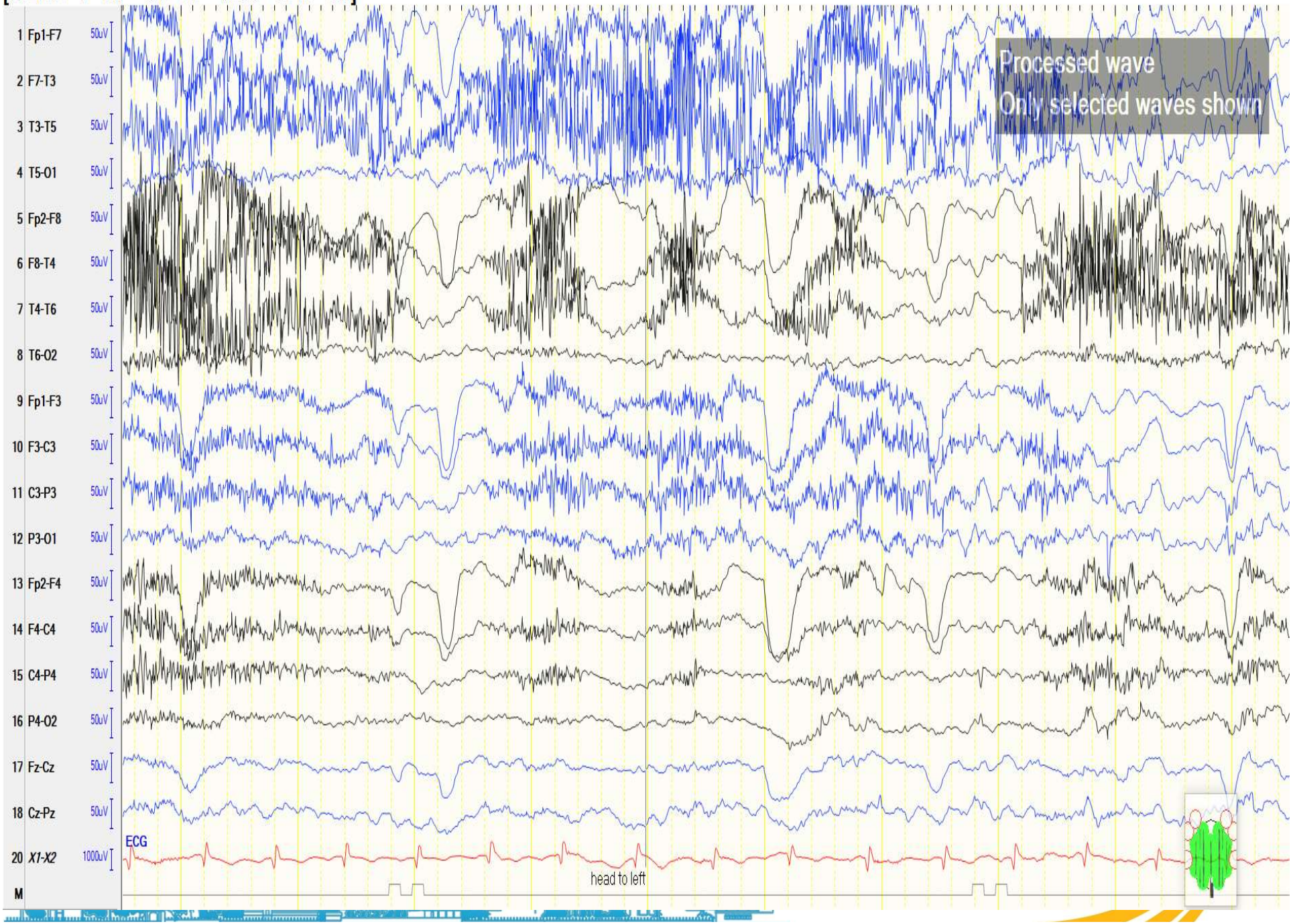
3 T3-T5 50uV
4 T5-O1 50uV
5 Fp2-F8 50uV
6 F8-T4 50uV
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
HR 90
Processed wave
Only selected waves shown
Interictal EEG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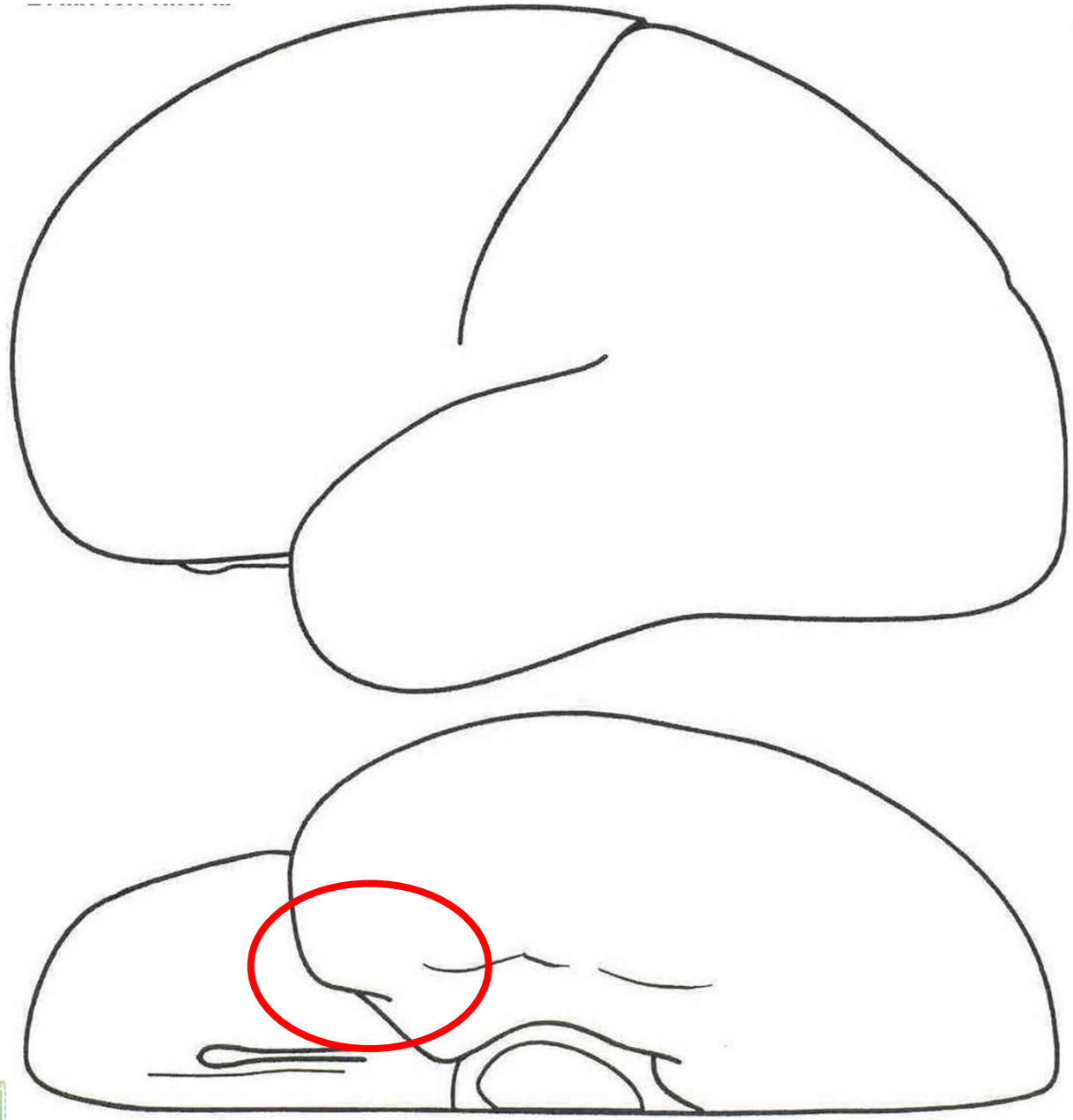
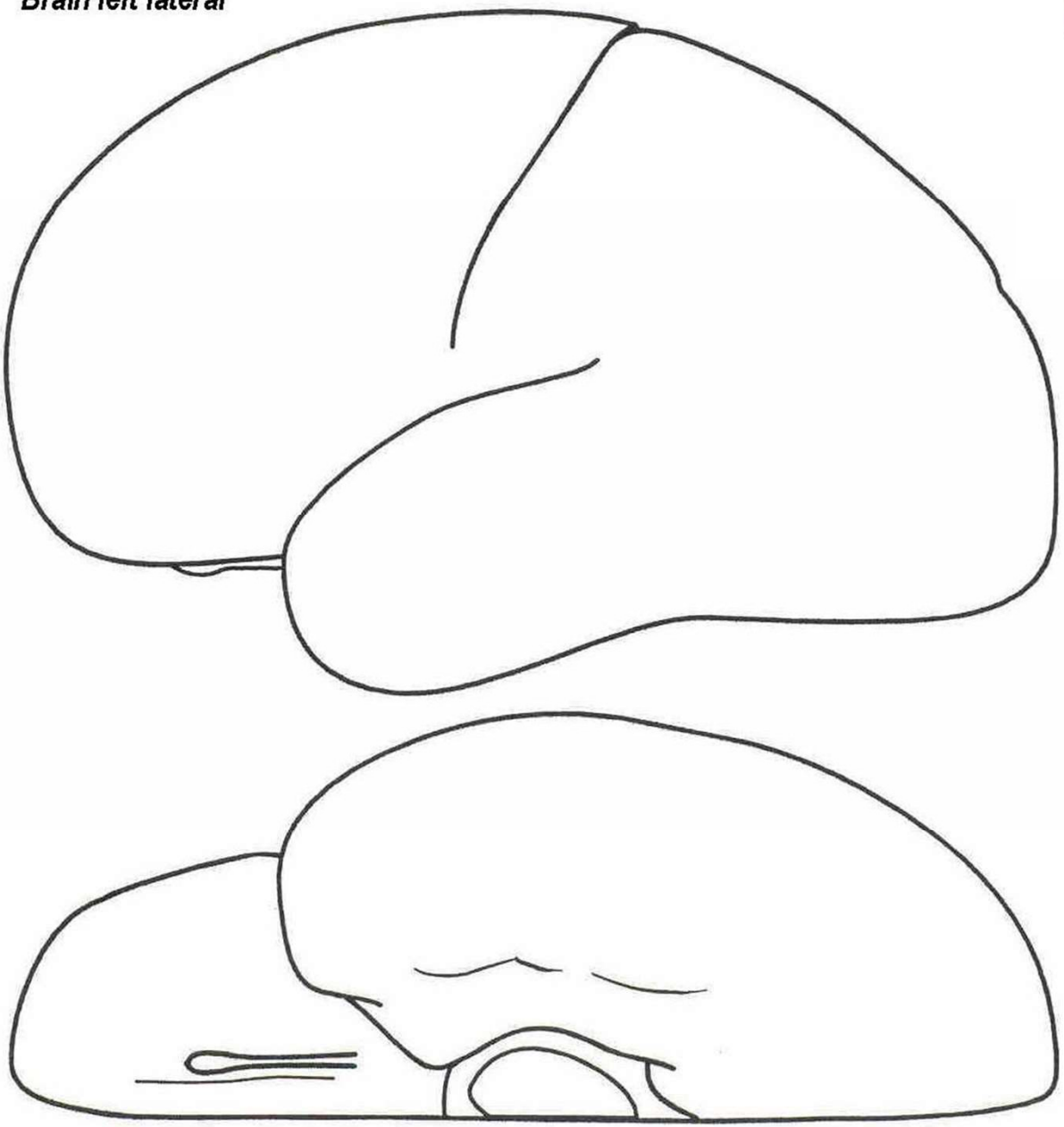
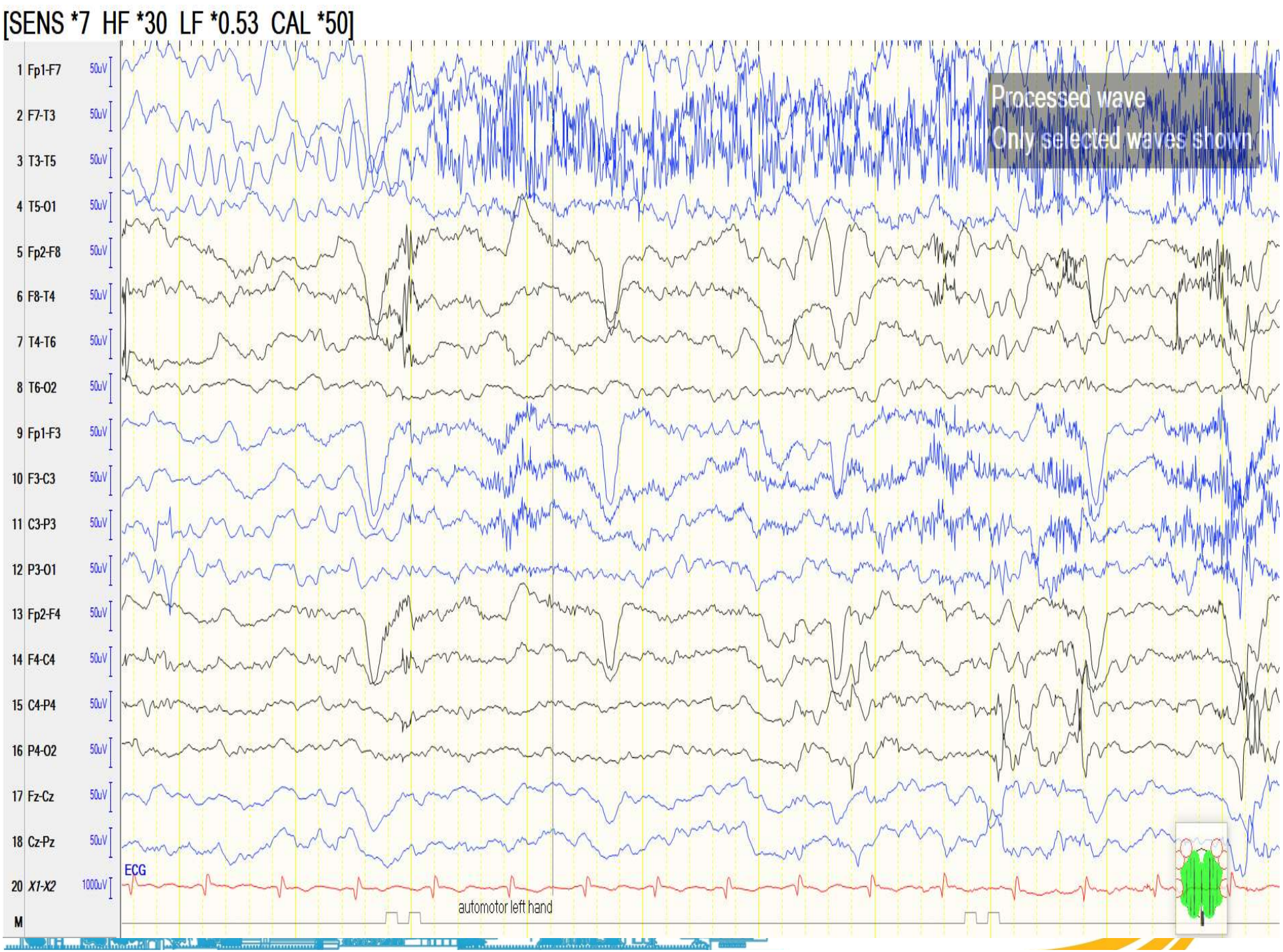
5 Fp2-F8 50uV
6 F8-T4 50uV
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
Processed wave
Only selected waves shown
head to left



Brain left lateral

Cleveland Clinic

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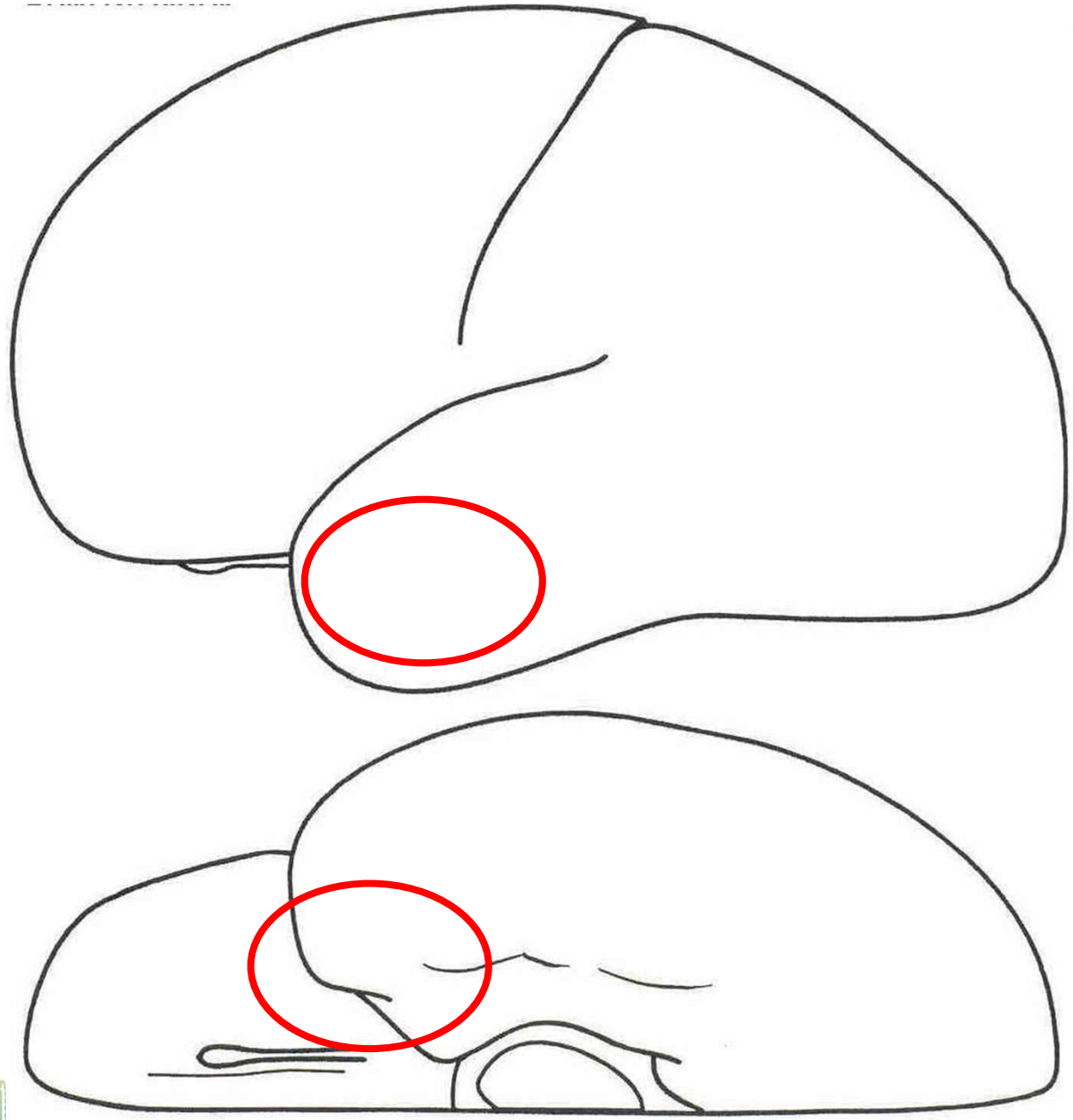
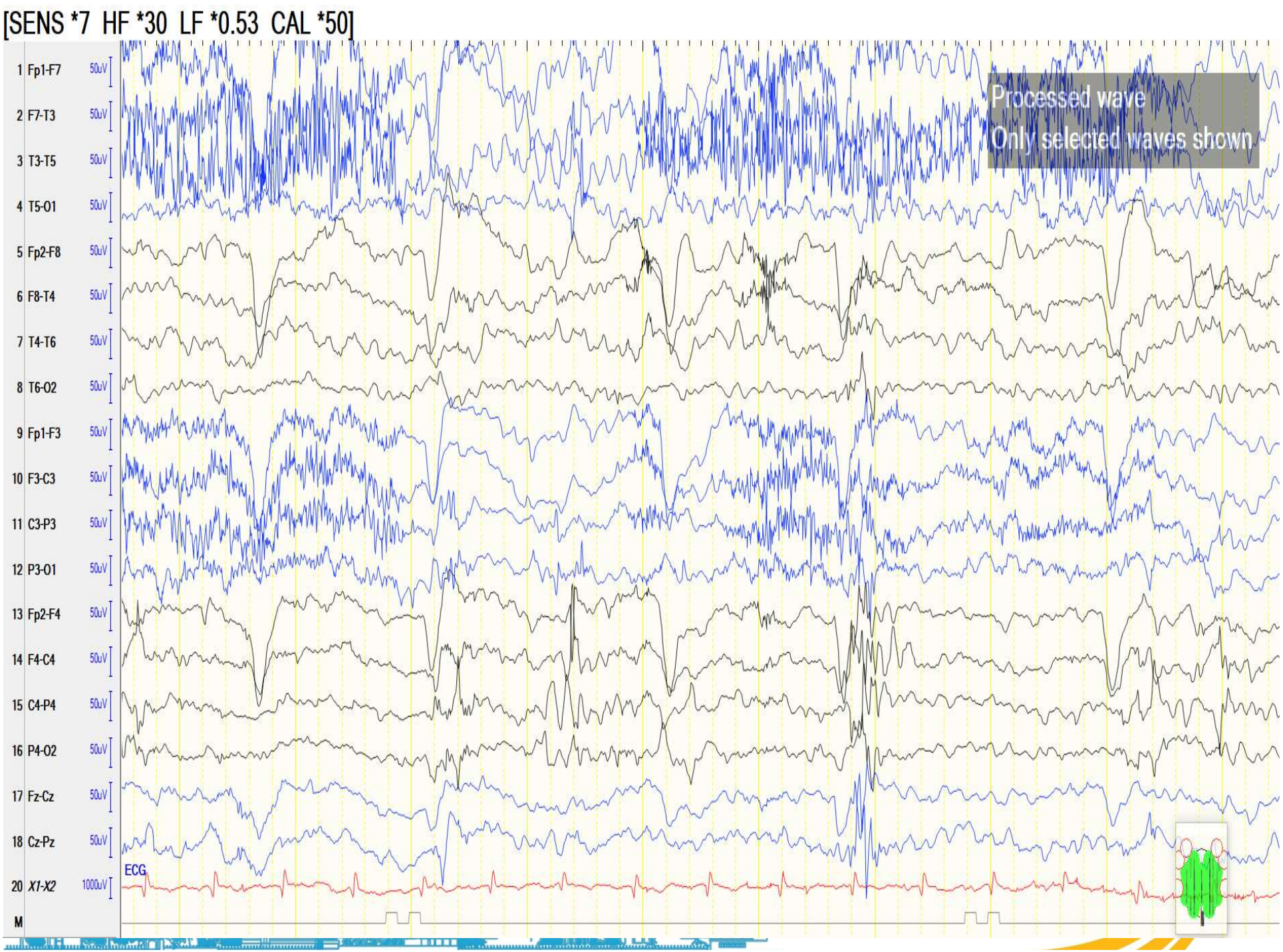
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
automotor left hand
Processed wave
Only selected waves shown

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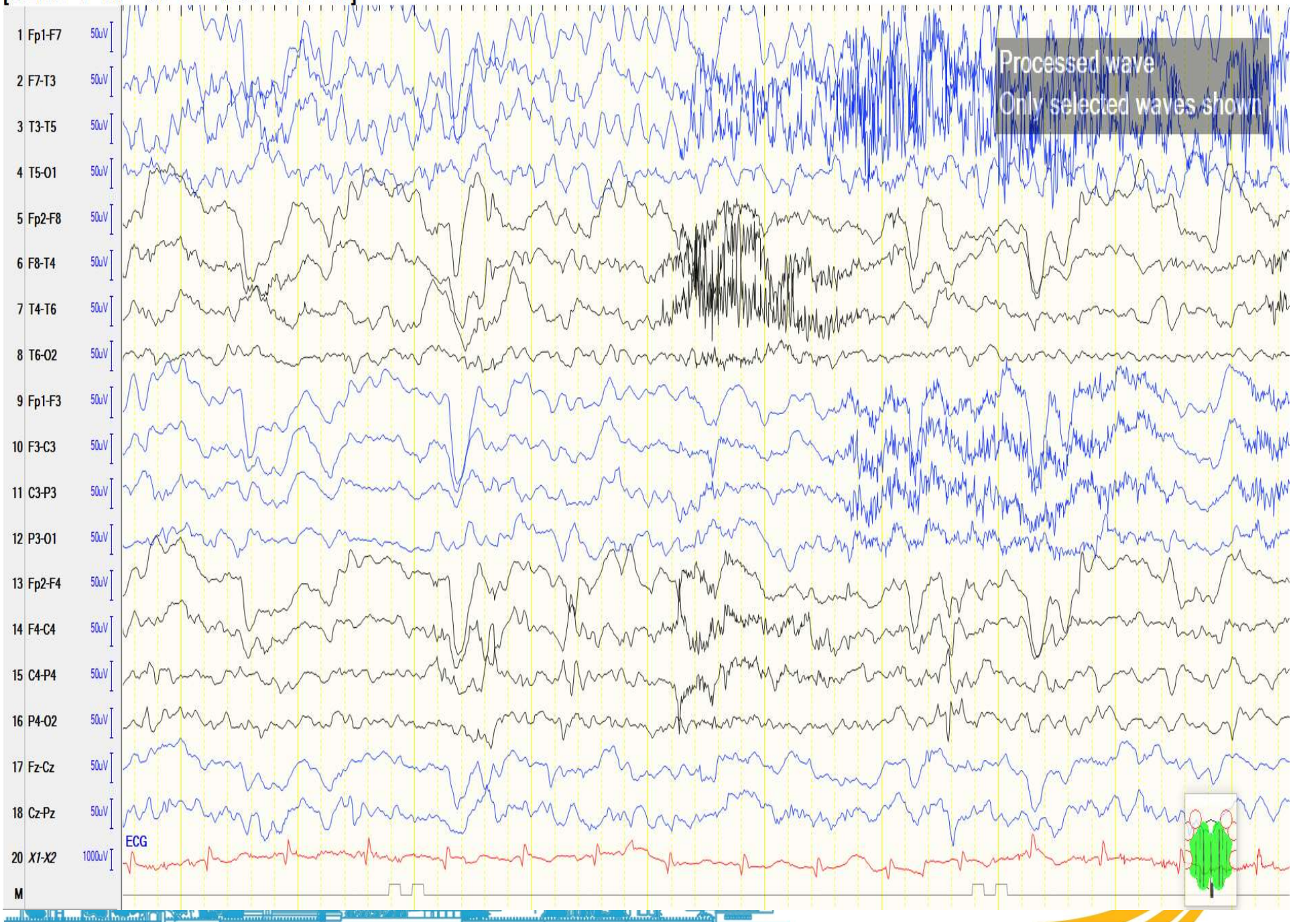
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
Processed wave
Only selected waves shown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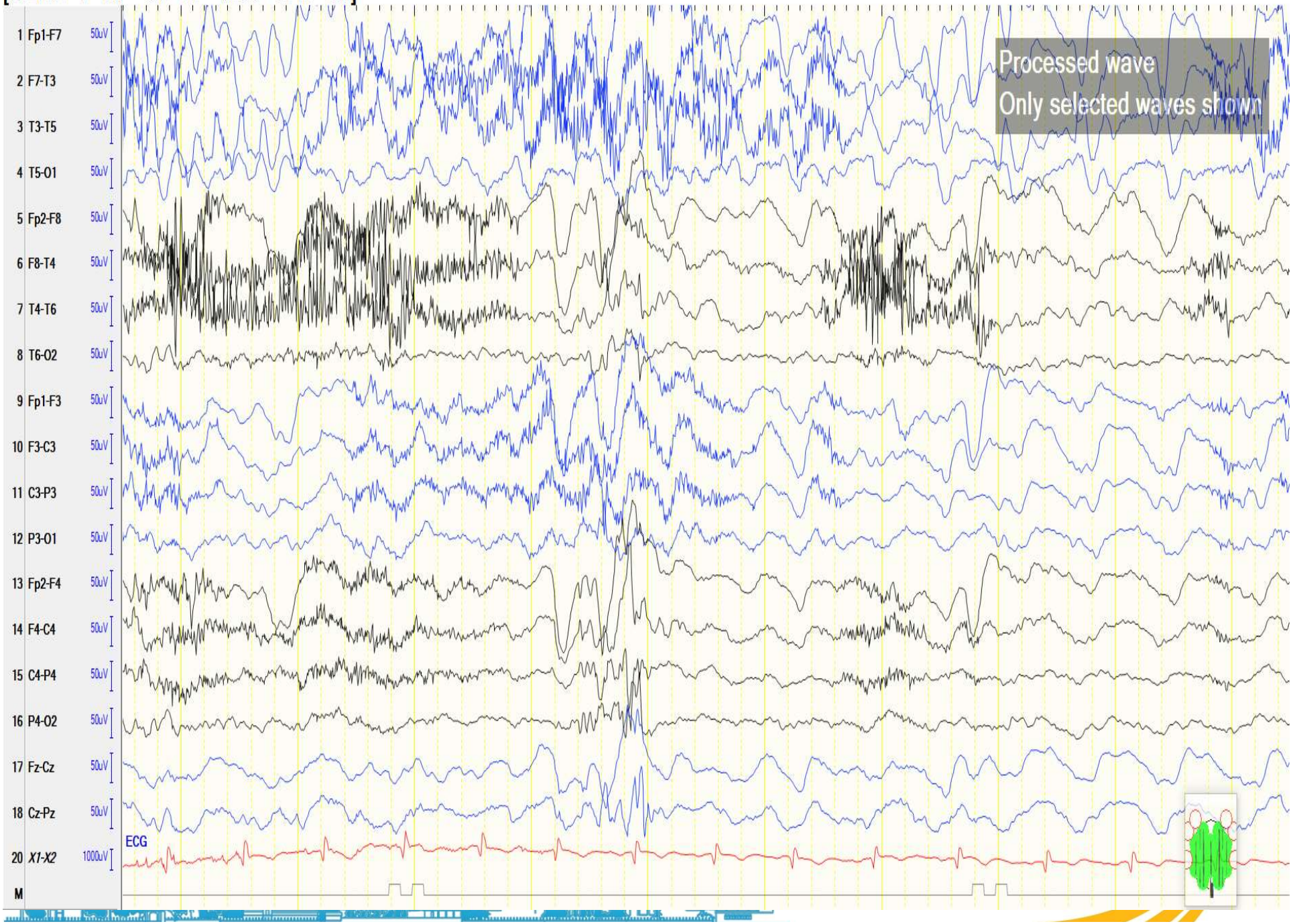
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
Processed wave
Only selected waves shown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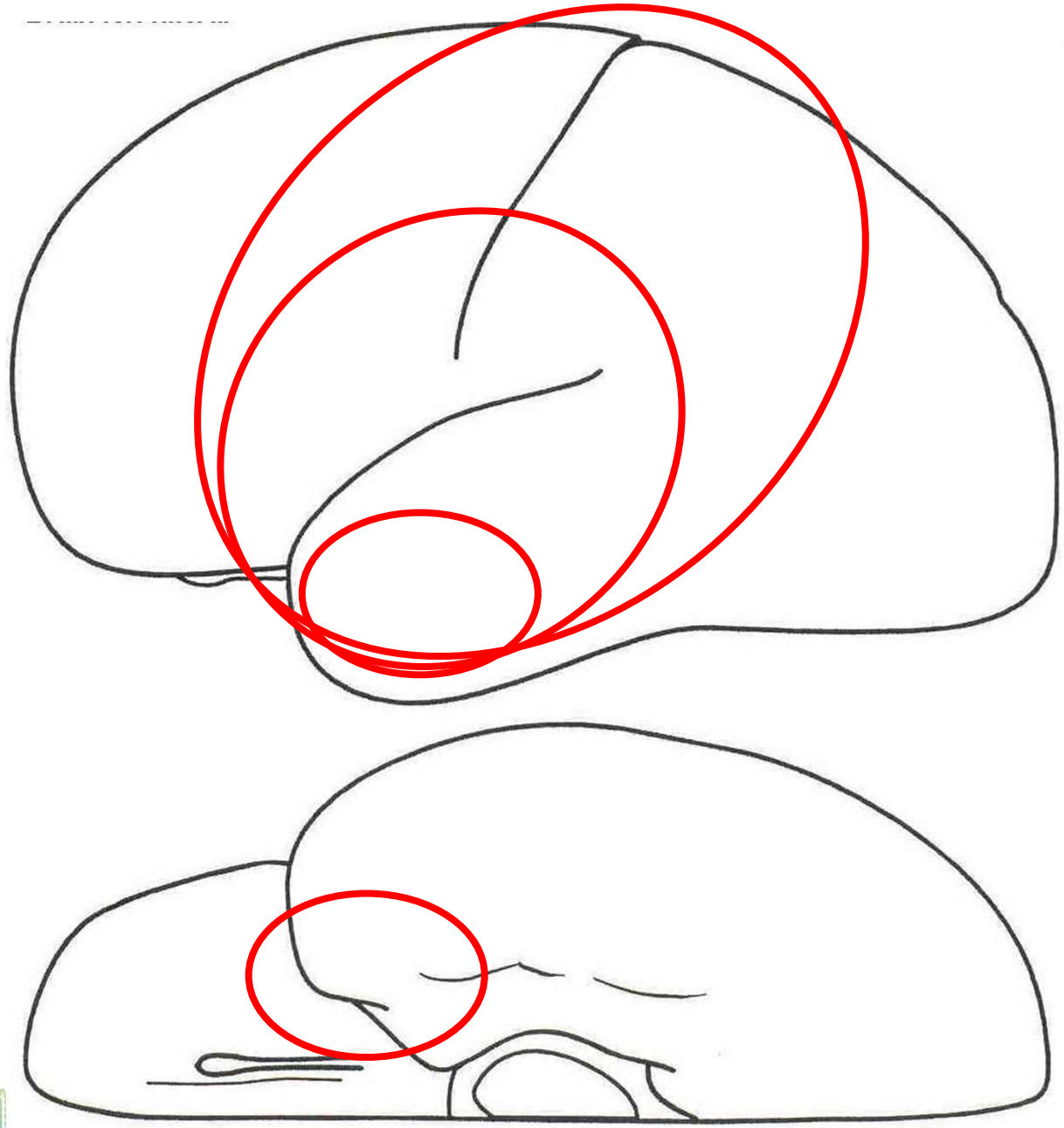
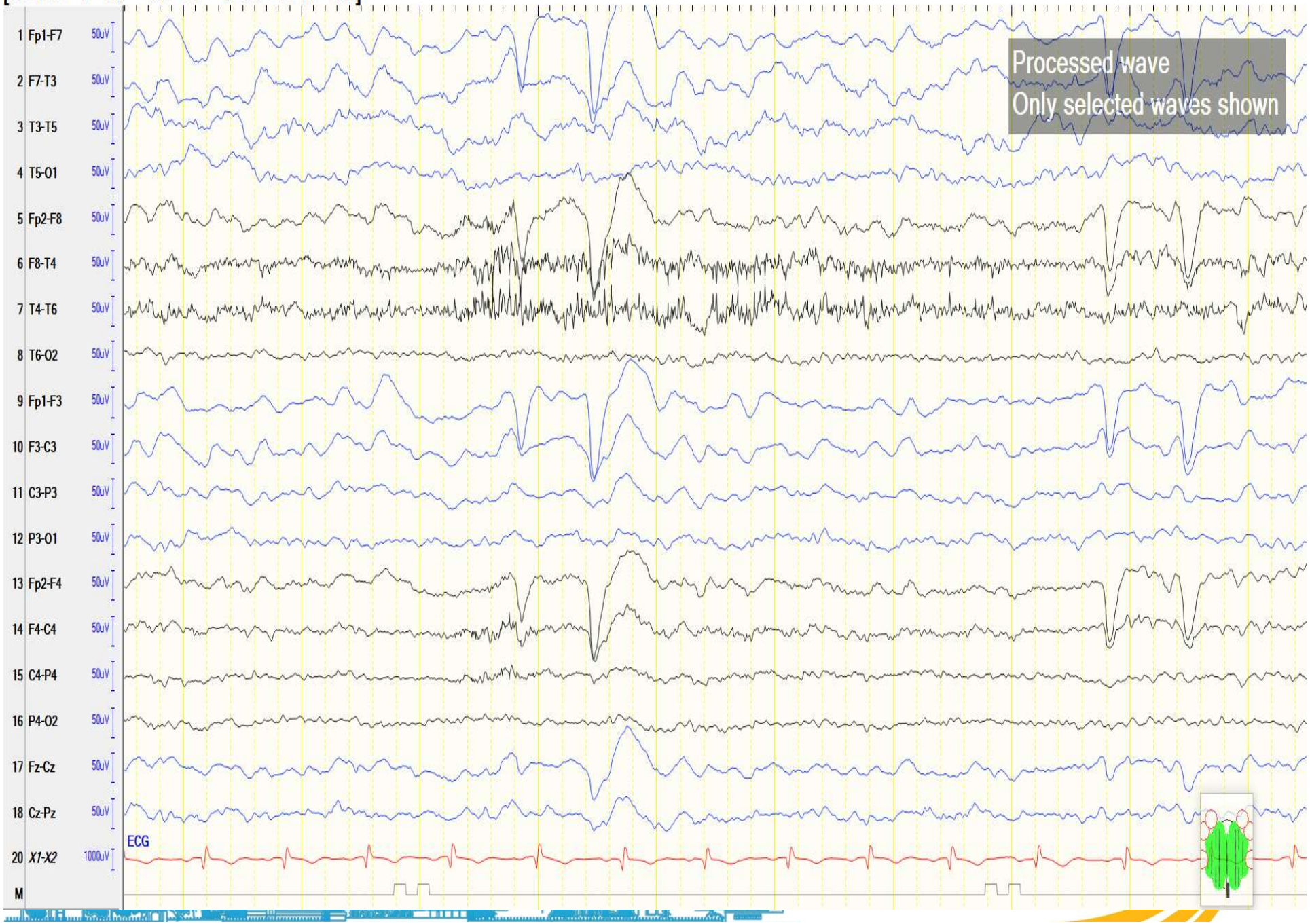
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
Processed wave
Only selected waves shown

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3 T3-T5 50uV
4 T5-O1 50uV
5 Fp2-F8 50uV
6 F8-T4 50uV
7 T4-T6 50uV
8 T6-O2 50uV
9 Fp1-F3 50uV
10 F3-C3 50uV
11 C3-P3 50uV
12 P3-O1 50uV
13 Fp2-F4 50uV
14 F4-C4 50uV
15 C4-P4 50uV
16 P4-O2 50uV
17 Fz-Cz 50uV
18 Cz-Pz 50uV
20 X1-X2 1000uV
M
ECG
Processed wave
Only selected waves shown

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34-year-old right-handed male, onset: 4 years old

- Seizures prior to surgery:
  - Type A: "Staring spells"
  - Type B: "Left arm clonic seizure -> GTC"

- Invasive evaluation with subdural grids/depths (2007) → Post right superior mesial frontal resection
- Pathology: subacute infarction, nonspecific changes

- Seizures after surgery:
  - Type A: “Dialeptic”

What is the cause of failure of resective epilepsy surgery?

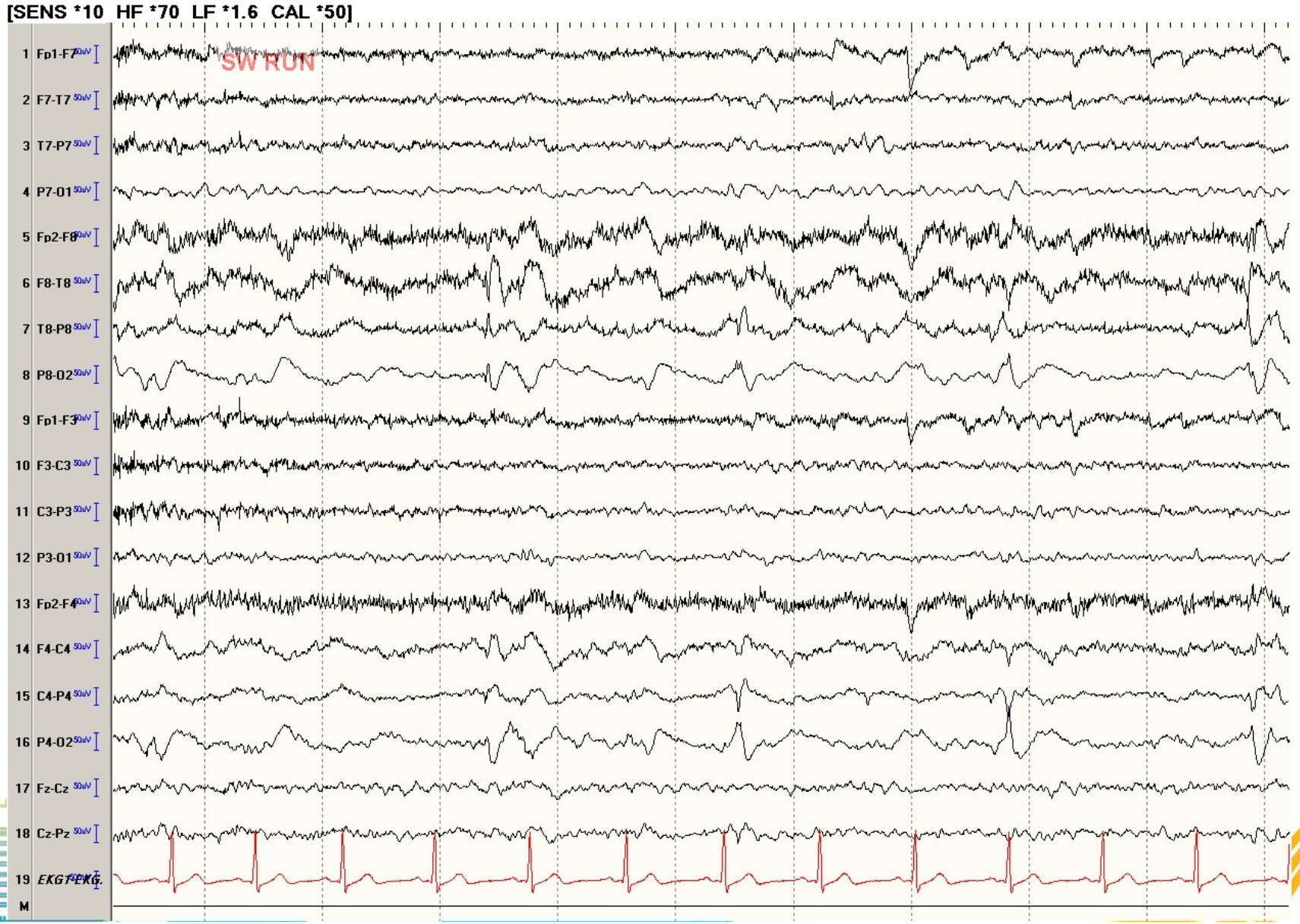
1.Inability to remove entirely epileptic cortex, functional?

2.Misidentify or mislocalize epileptic focus

3.Multiple epileptic foci

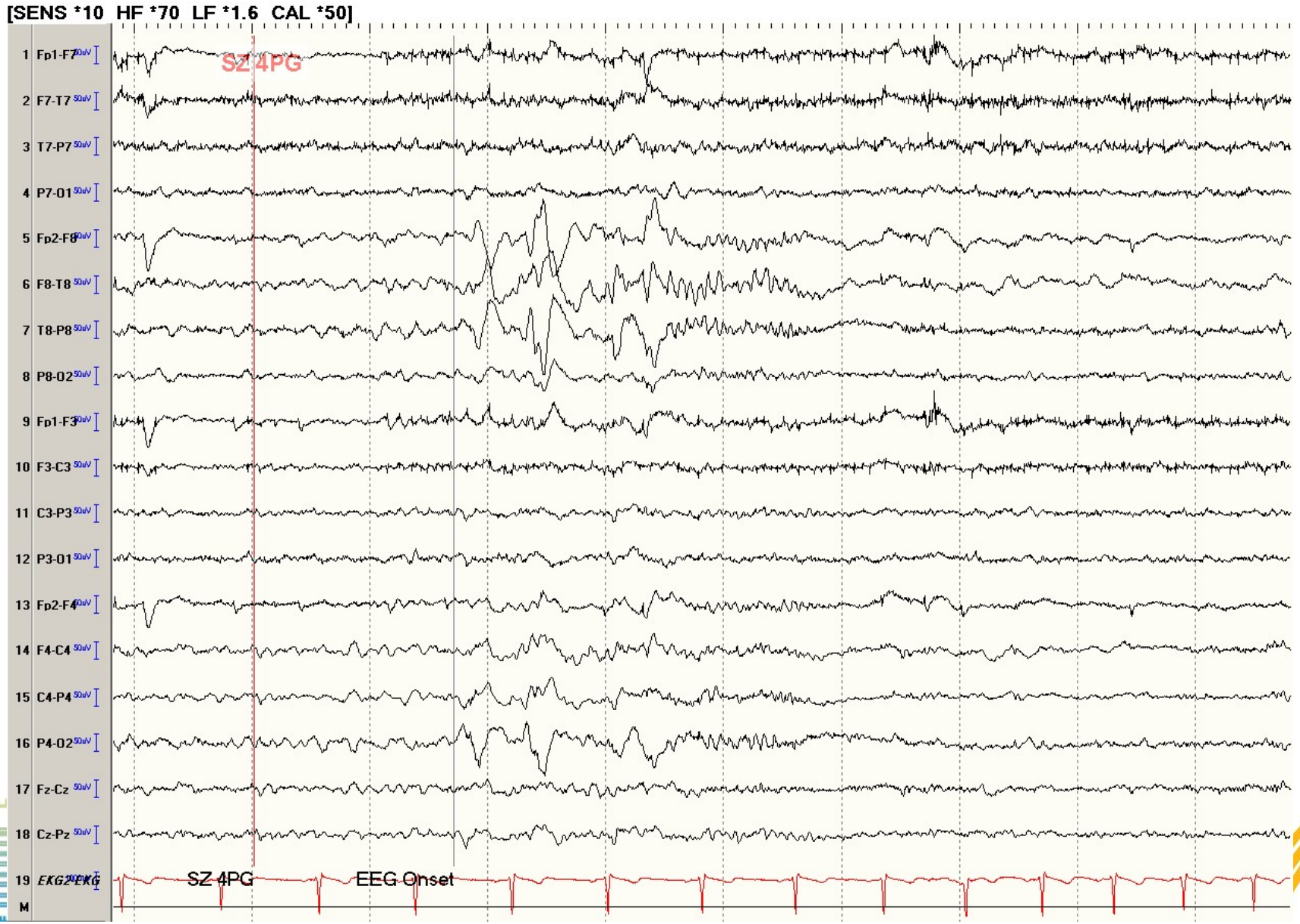
4.Natural course

SW T8/P4 (in runs)



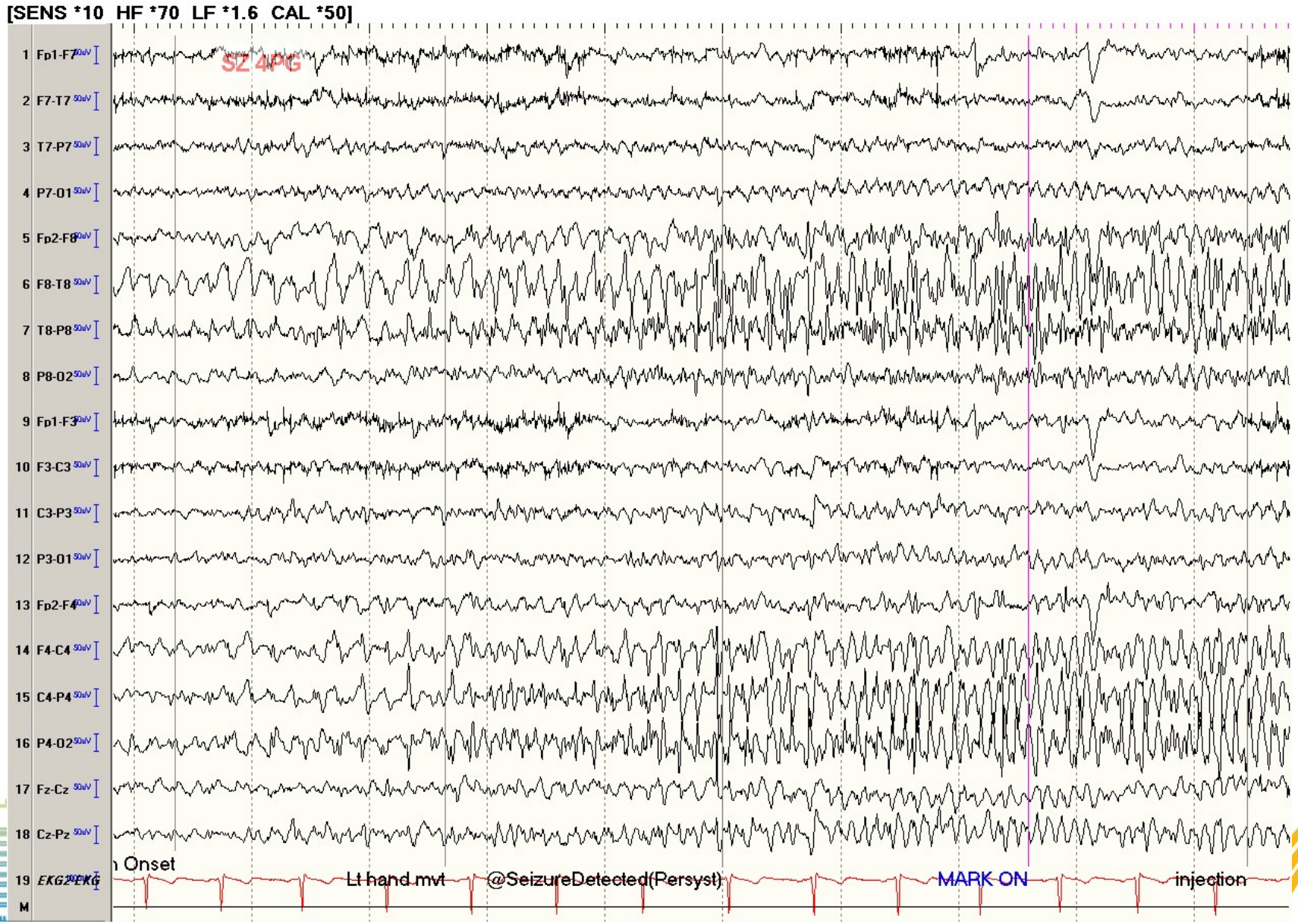
SZ 4PG onset:

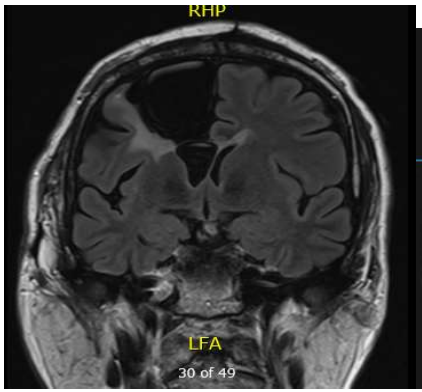
Automotor → Left arm Clonic → Left head Versive → GTC seizure

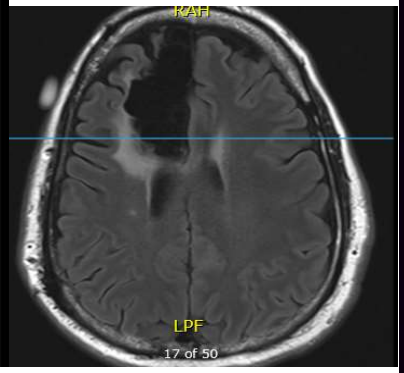


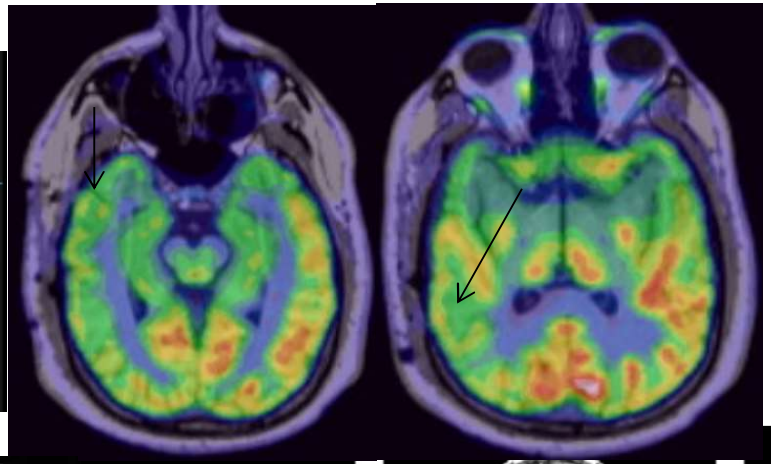
SZ 4PG +10s

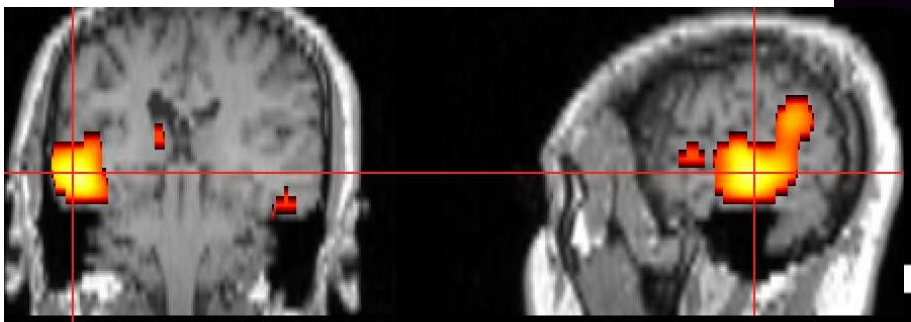
EEG: Regional right centrotemporoparietal

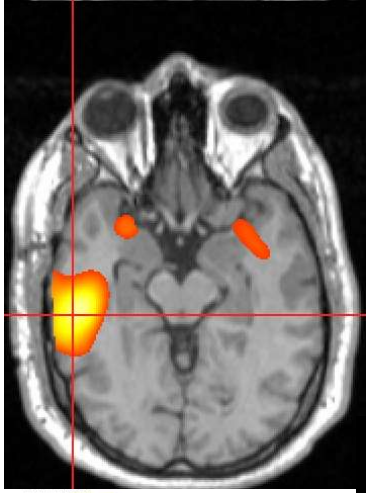






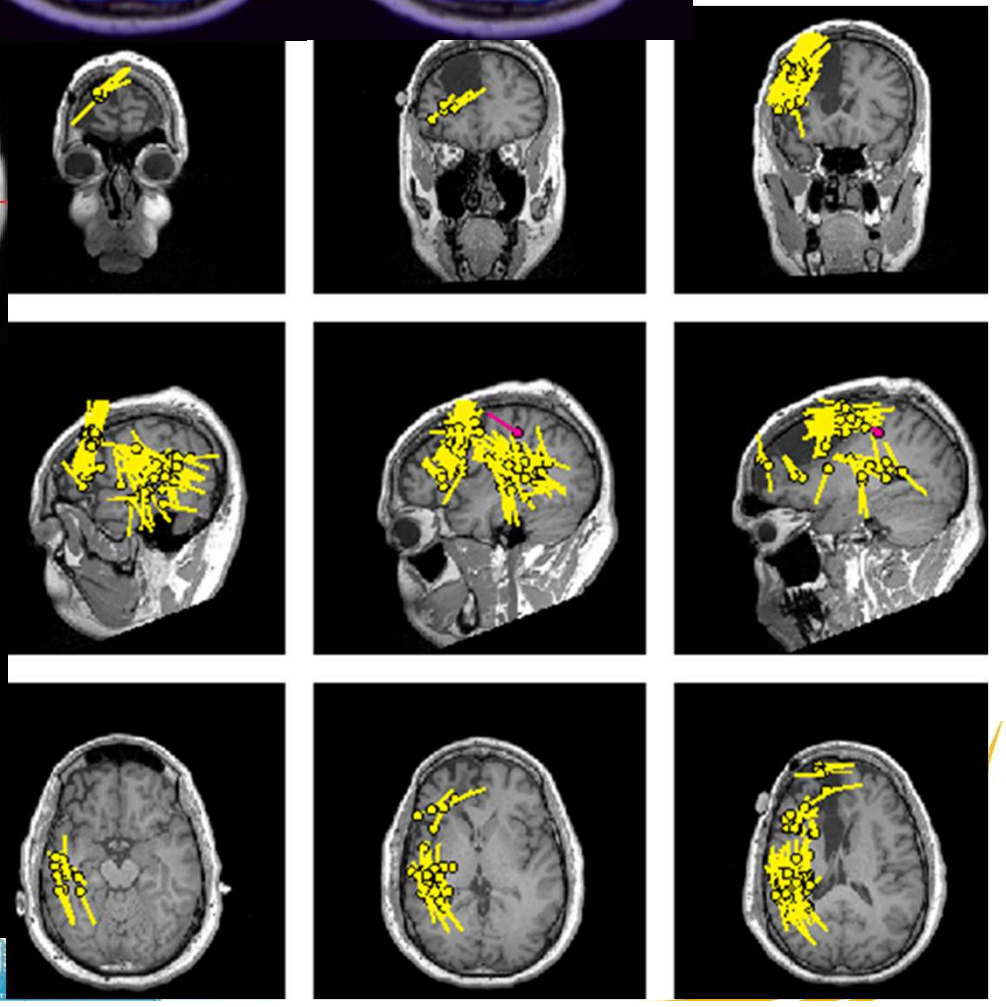




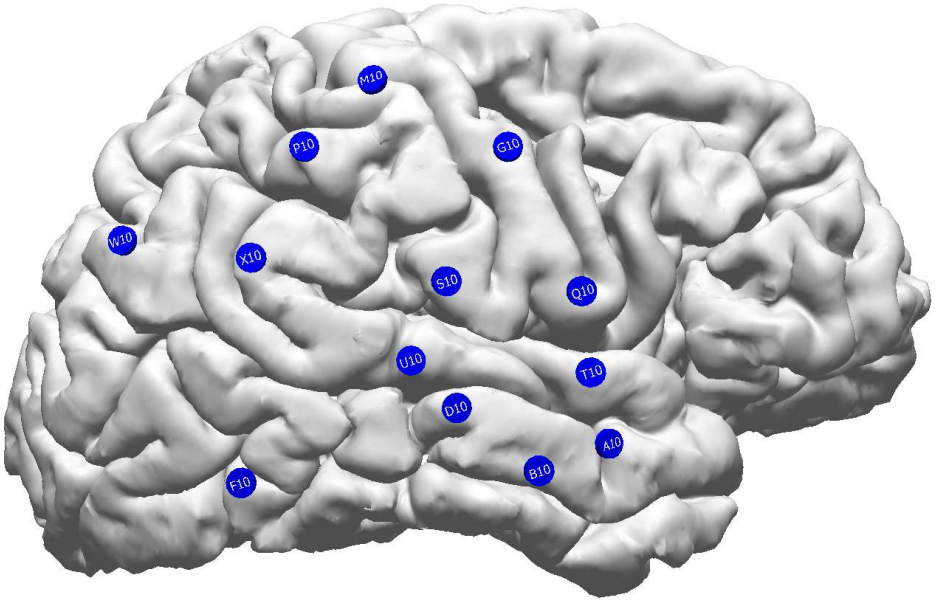


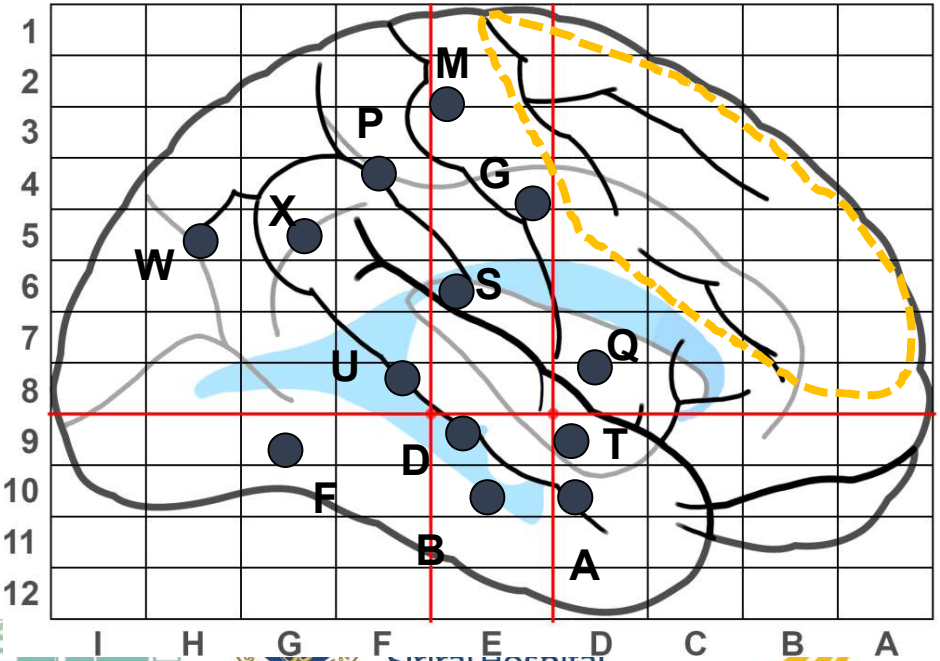
Right mid to posterior lateral temporal region

Hypothesis:
Right TP junction
Right posterior temporal



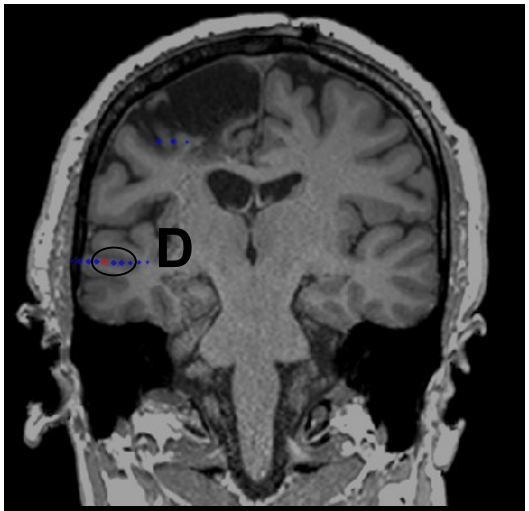
Hypothesis:
Right TP junction
Right posterior temporal

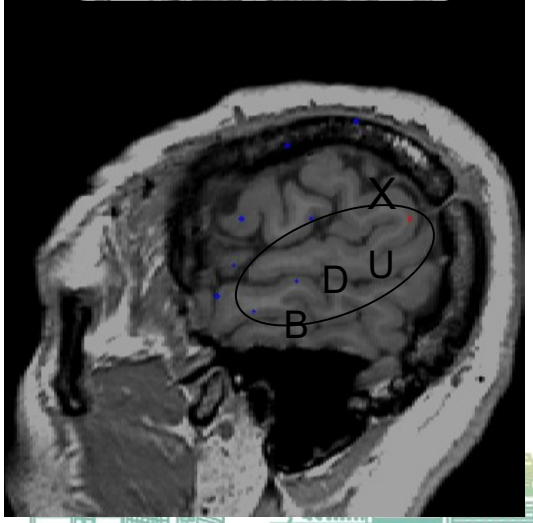


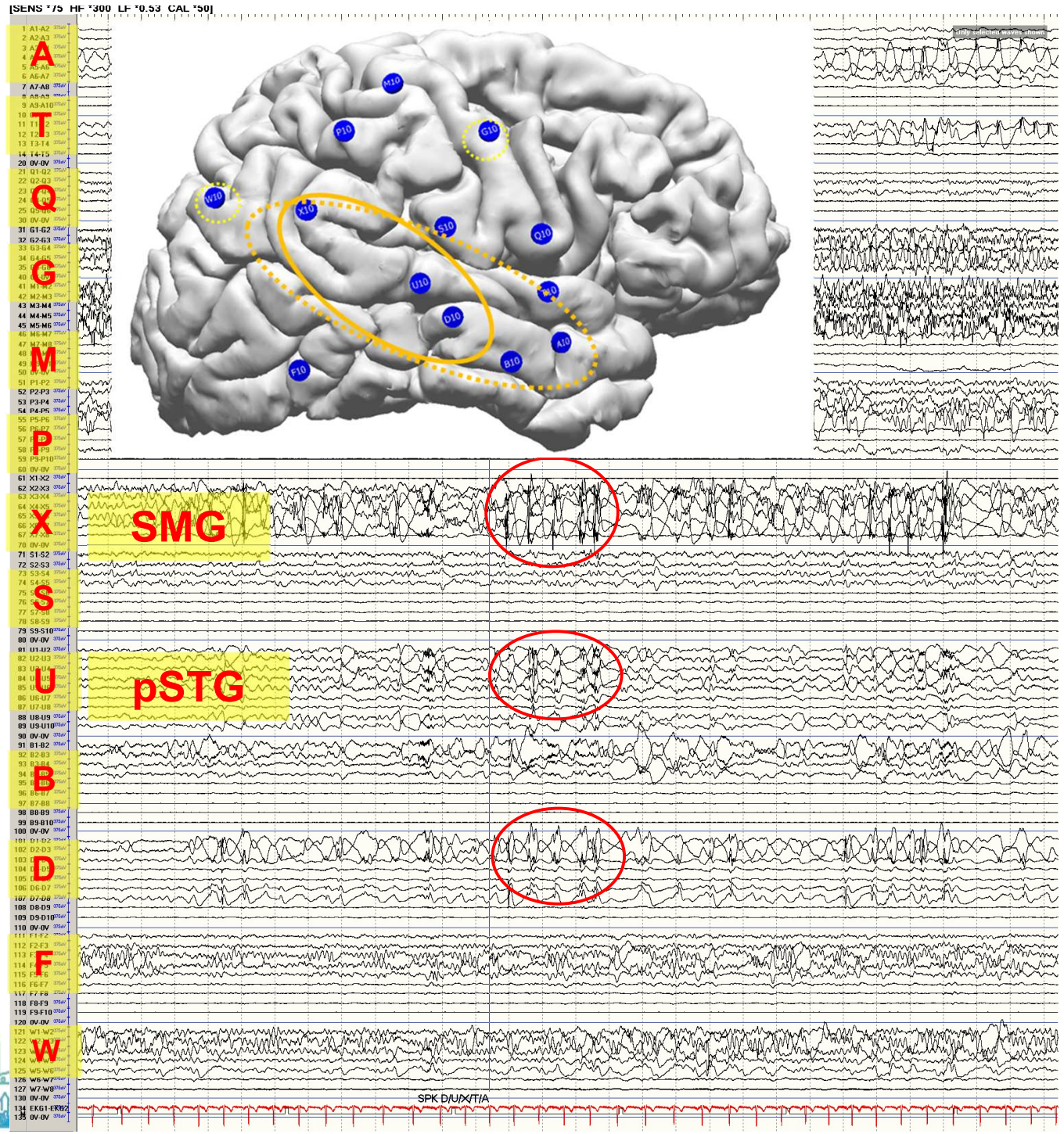


SPK B1-5/U2-6/D3-7/X4-7 (SMG/pSTG/MTG)

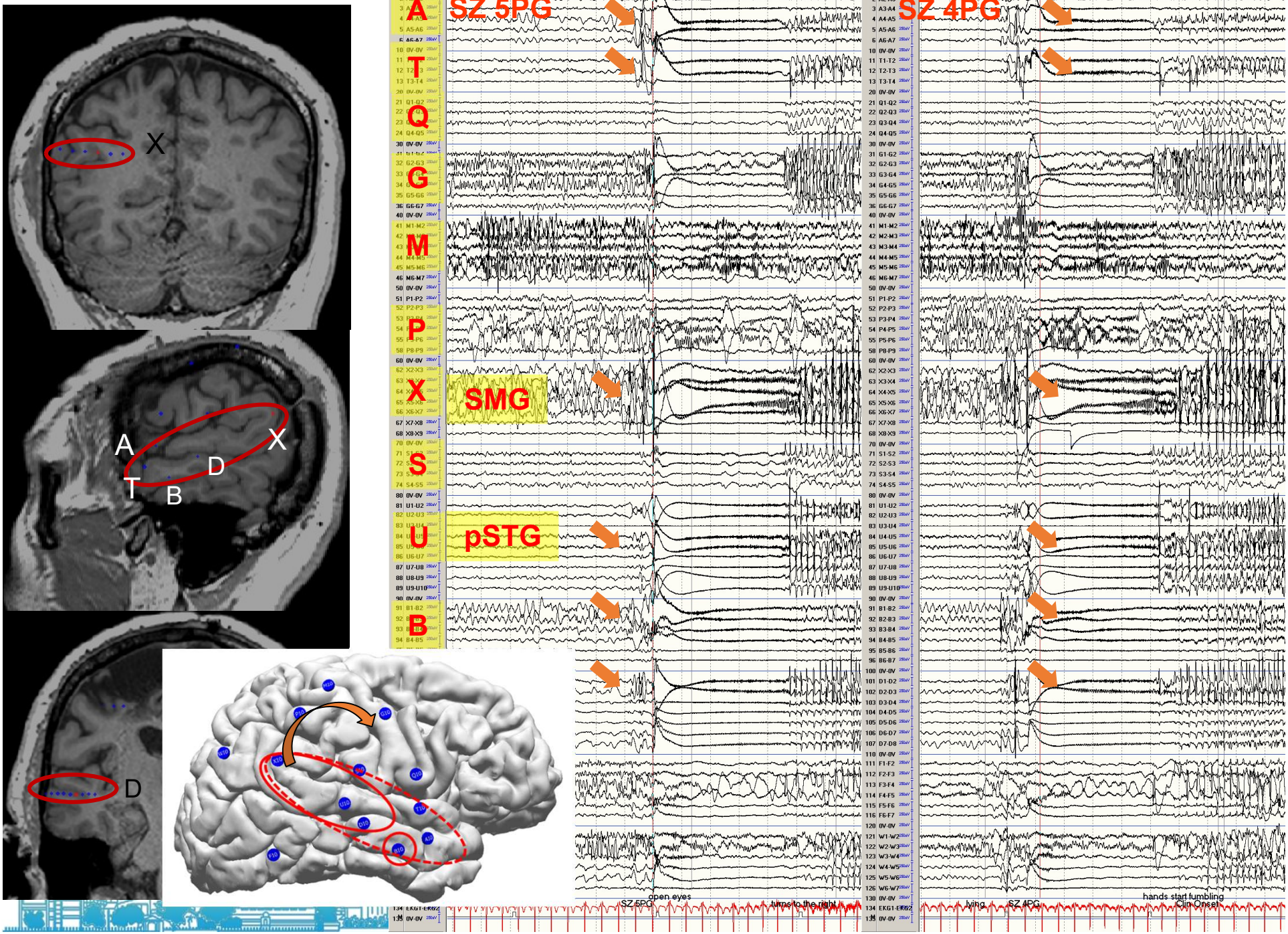
In bursts every 10-30 sec



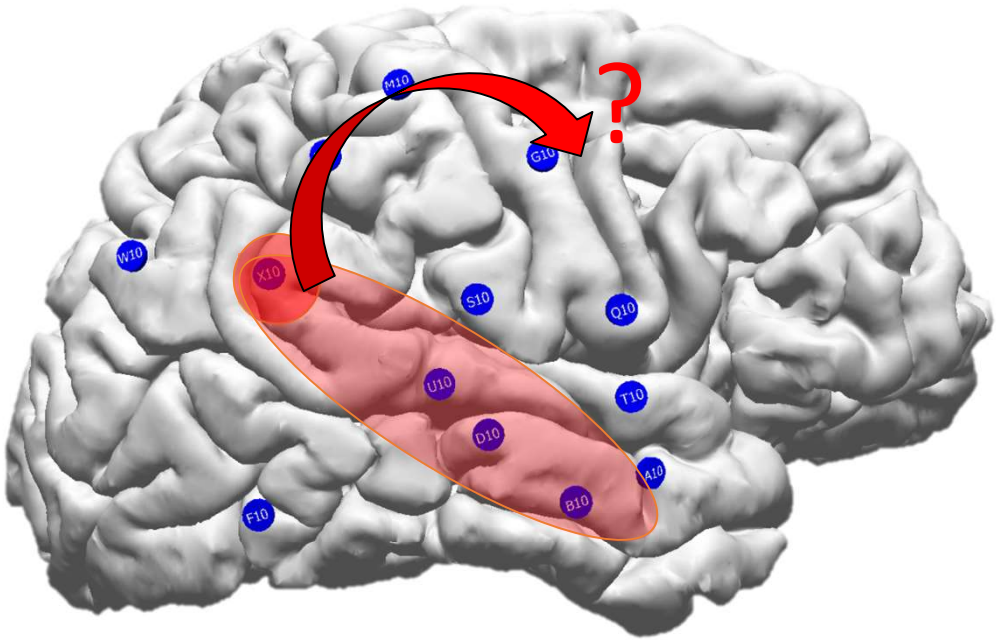




hands grasping movements → eyes / head to the right → left face clonic → left eyes and head versive → GTC


X
A
T
D
B
X
D
SZ 5PG
SZ 4PG
SMG
pSTG
A
T
Q
G
M
P
X
S
U
B
SZ 5PG
open eyes
turns to the right
lying
SZ 4PG
hands start fumbling
Clin Onset

Spreading: Neural Network ??



มหาวิทยาลัยมหิดล
คณะแพทยศาสตร์
ศิริราชพยาบาล

Parietal Lobe Epilepsy and It's Network

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Faculty of Medicine
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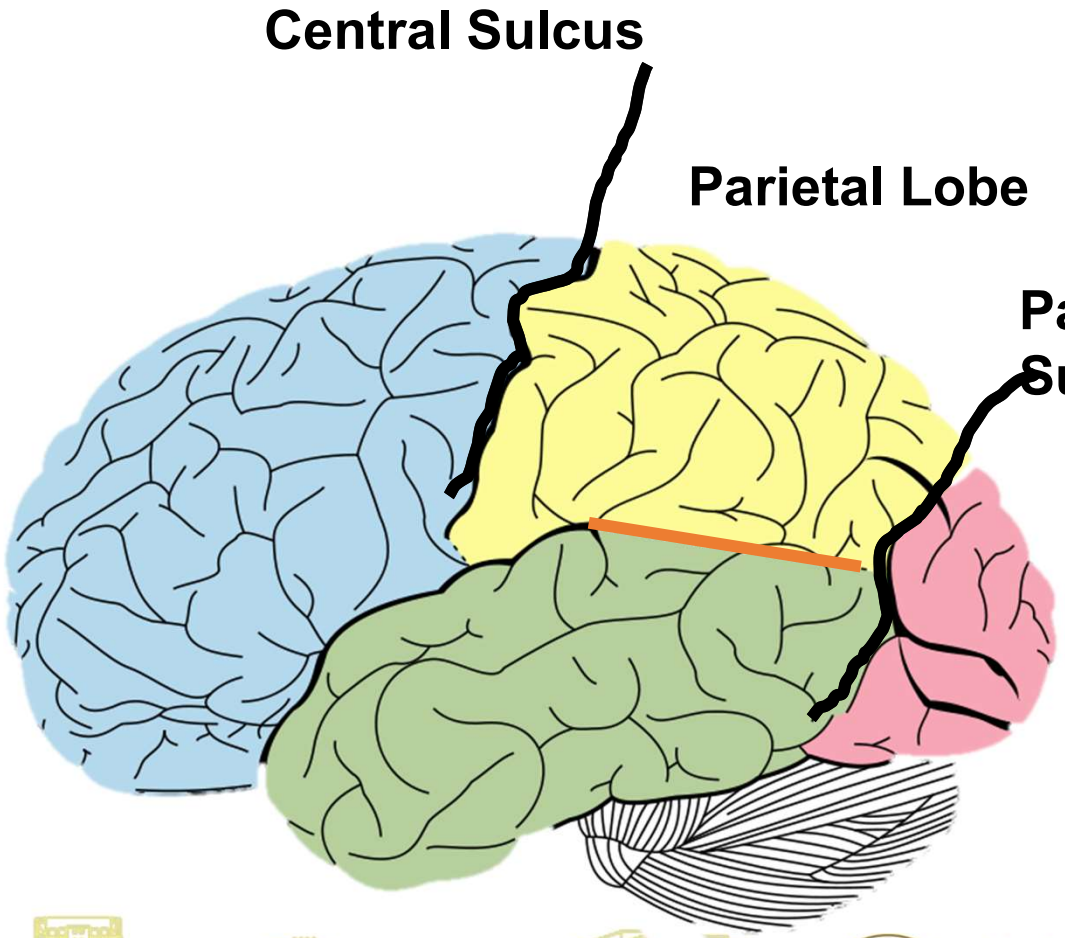
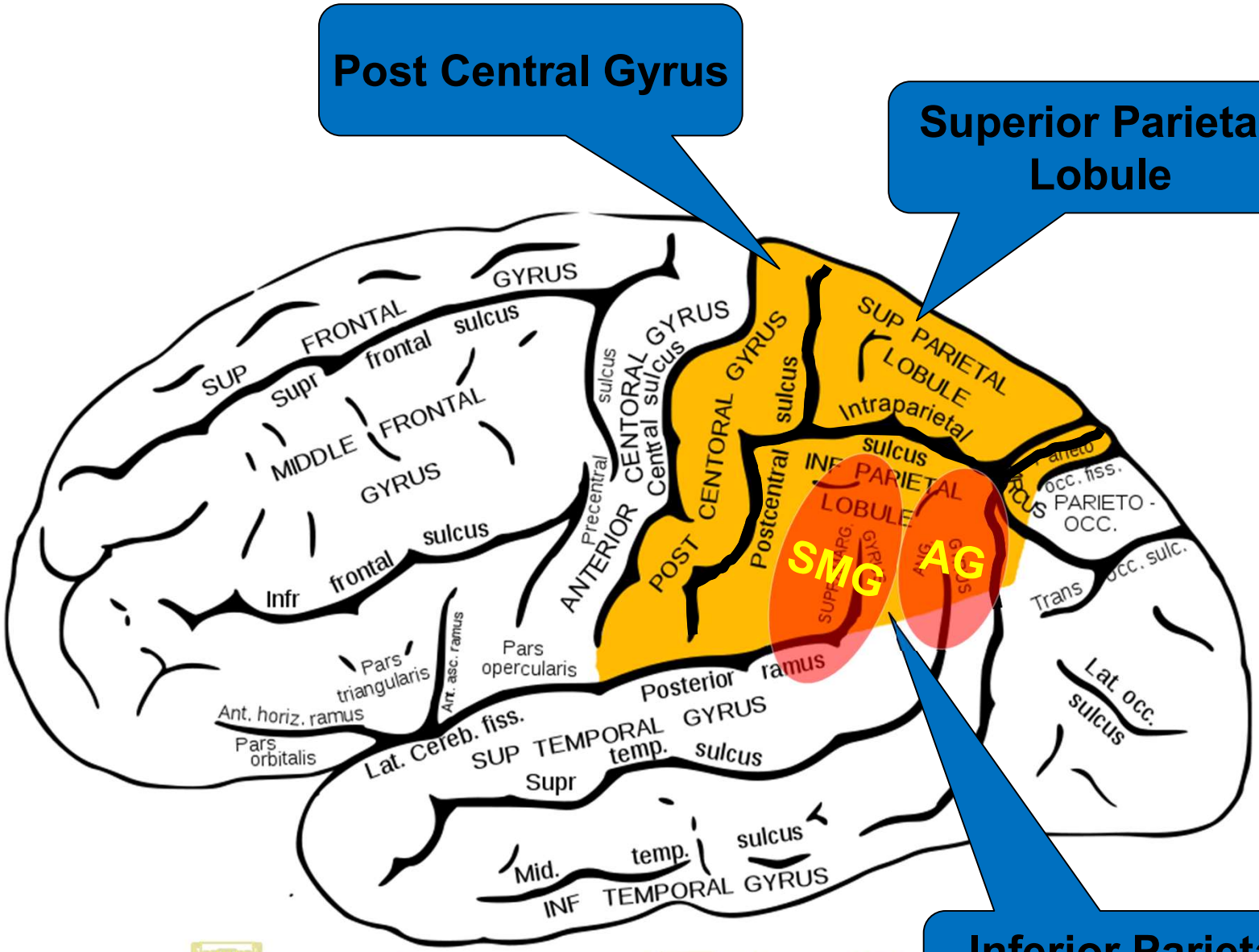
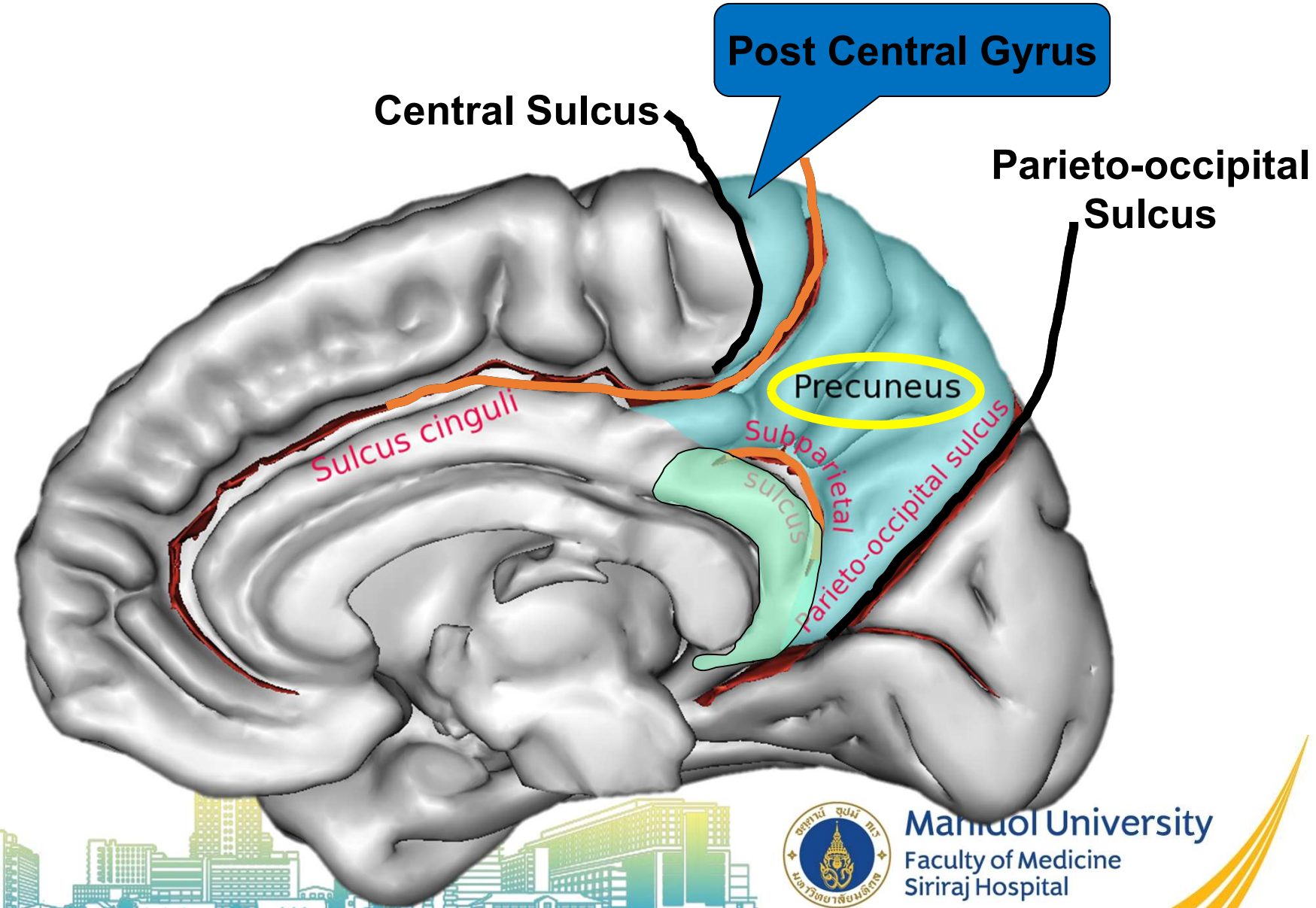
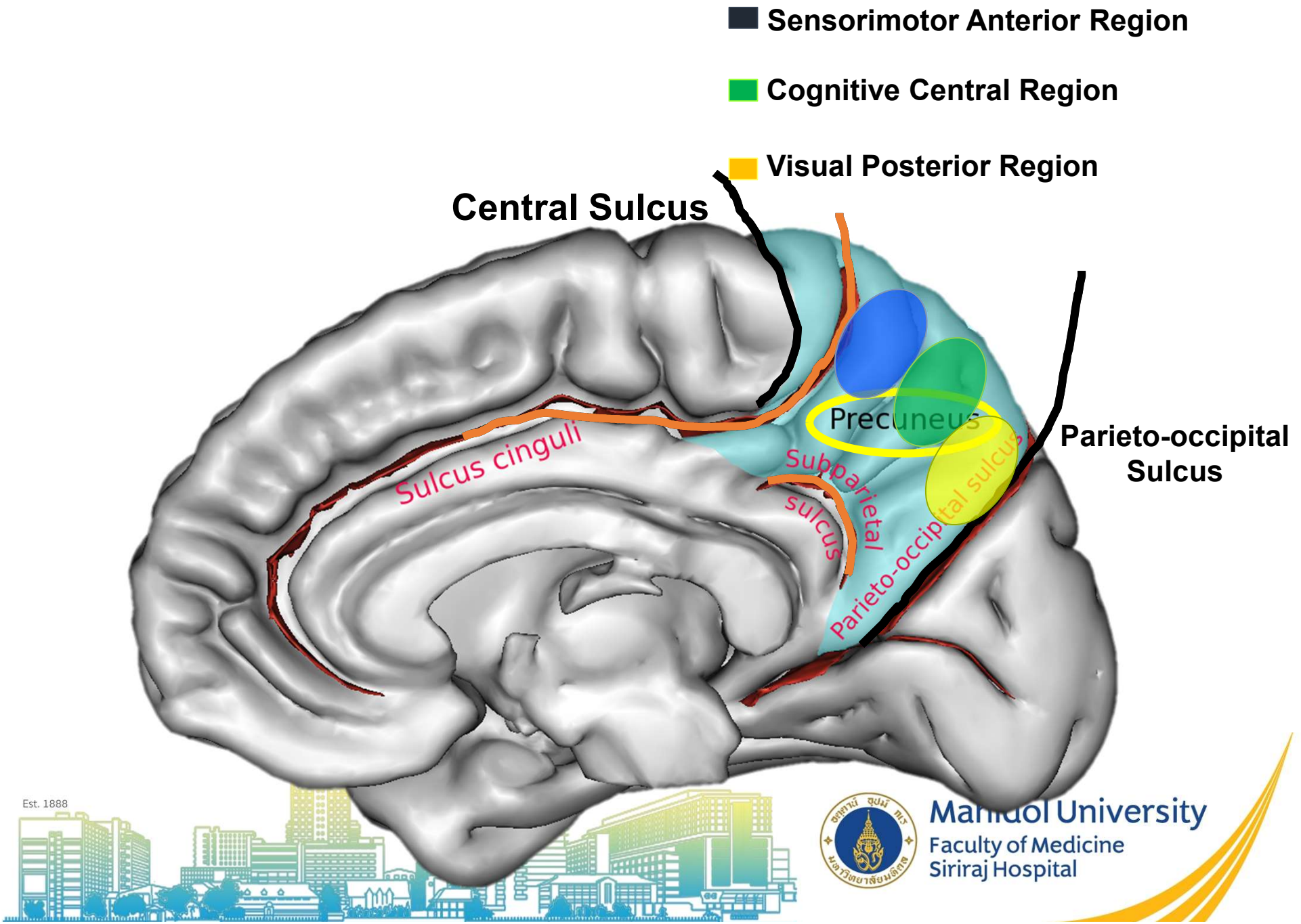
Anatomy: Dorsal Surface



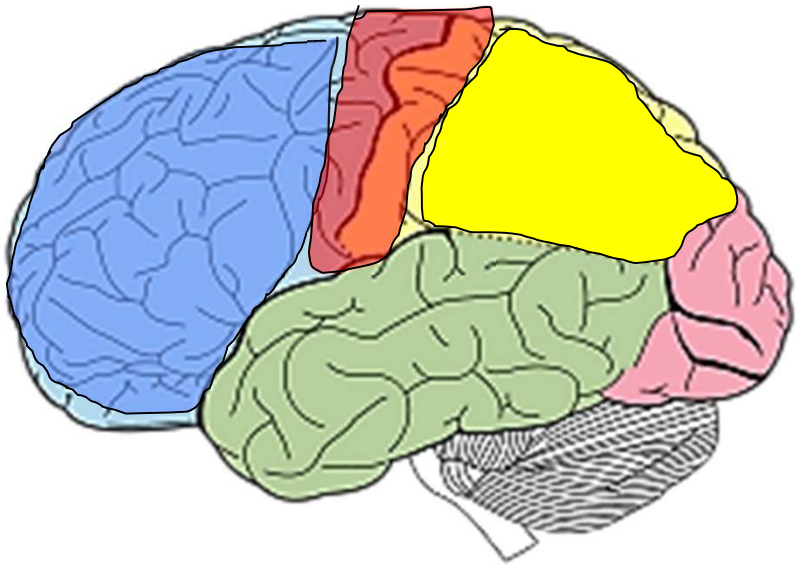


Anatomy: Medial Surface




Sensorimotor Anterior Region
Cognitive Central Region
Visual Posterior Region
Central Sulcus
Precuneus
Parieto-occipital Sulcus
Sulcus cinguli
Subparietal sulcus
Parieto-occipital sulcus
Est. 1888
Mahidol University
Faculty of Medicine
Siriraj Hospital

Epileptogenic areas were divided into



- Frontal
- Central: perirolandic (sensorimotor area)
- Parietal
- Temporal
- Occipital regions

Parietal epilepsy:
"Parietal area lies behind the post central gyrus"
→ "parietal association area"

Penfield W, et al. New York: Macmillan, 1950:135-44
Salanova V, Brain 1995;118:607-27

Prevalence

- Not common, 6% of operated pt (total 82 pts)[1]
- Cleveland Clinic (1996-2009)[2]
  - 131/1,212 pts underwent posterior quadrant (parietal and/or occipital lobes) resections

Clinical manifestations

Symptomatogenic Zone
≠
Seizure Onset Zone

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1. Salanova V. Brain 1995;118:607-27
2. Jehi L, et al. Unpublished data

Clinical manifestations

- Aura:
  - **Somatosensory**: tingling or numbness > painful > thermal
  - **Disturbance of body image**: sensory of movement or absent
  - **Vertigo**, cephalic aura
  - **Visual illusion**: “figures looks larger” or “things on the wall turning”
  - **Complex visual or auditory hallucinations**: ictal spread to temporo-limbic areas.

Salanova V, Brain 1995;118:607-27.

TABLE 2. *Auras in 40 patients with parietal lobe epilepsy*

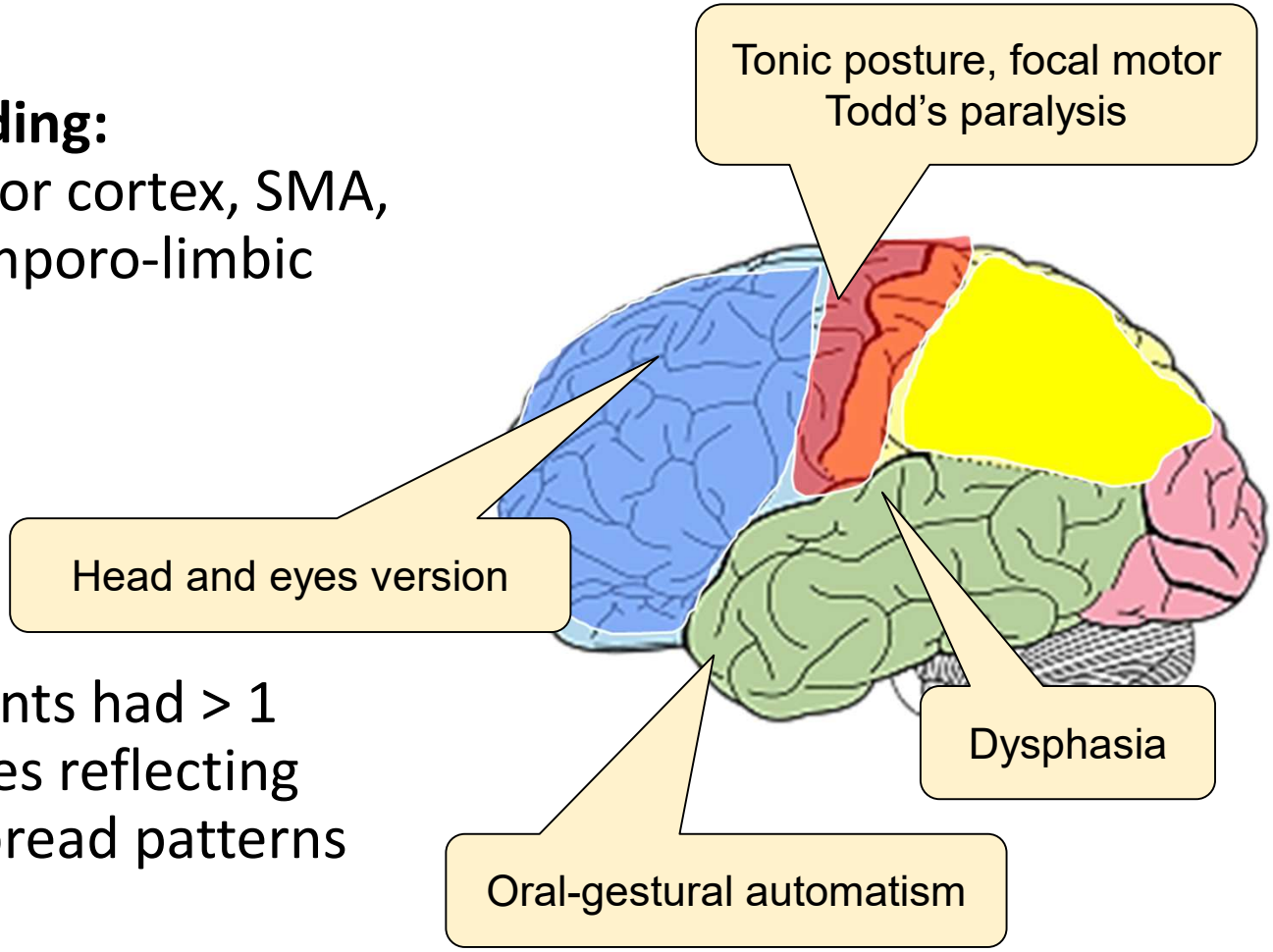
Aura	No. (%)
Somatosensory	13 (32.5)
Contralateral	10 (25)
Bilateral	2 (5)
Ipsilateral	1 (2.5)
Affective	6 (15)
Vertigo	4 (10)
Visual	4 (10)
Autonomic	3 (7.5)
Gustatory	3 (7.5)
Auditory	1 (2.5)
Mnemonic	1 (2.5)

Aura was present in 27 (67.5%) of 40 patients.

Kim DW, et al. Epilepsia 2004;45:641-9

Other seizure characteristics

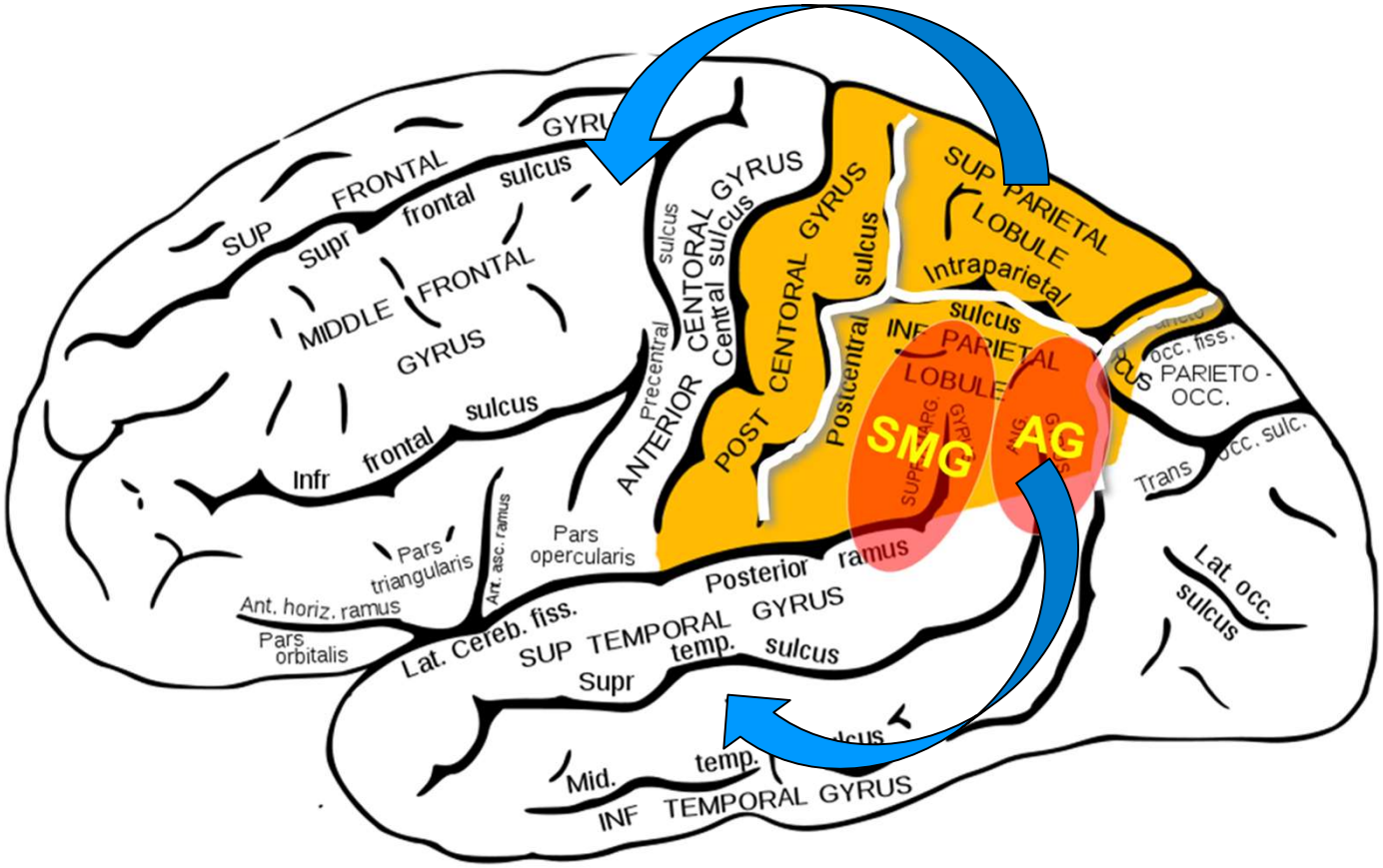
- **Ictal spreading:** sensorimotor cortex, SMA, FEF,and temporo-limbic region.



- Many patients had > 1 seizure types reflecting different spread patterns

Salanova V, Brain 1995;118:607-27.

SMA ← tonic / asymmetric tonic posturing ← SPL (61%)



Temporo-limbic areas ← automatisms ← IPL (79%)

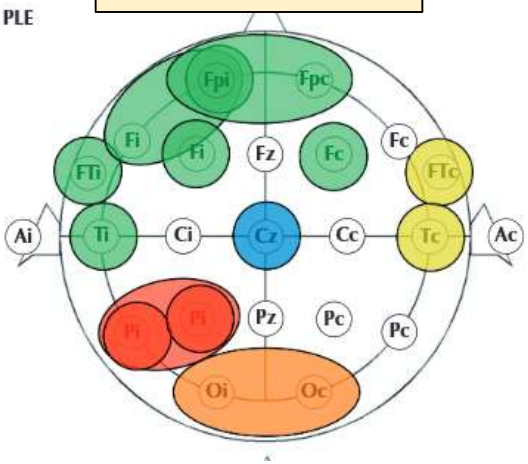
Resnick TJ, et al. Epilepsia 1993;34

Parietal lobe epilepsy: the great imitator among focal epilepsies

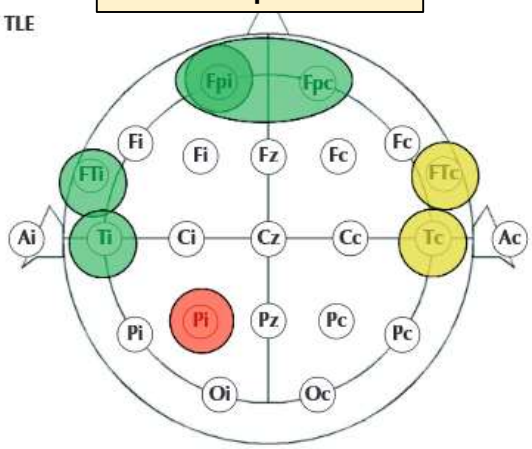
Aleksandar J Ristić [1,2], Andreas V Alexopoulos [1], Norman So [1], Chong Wong [1,3], Imad M Najm [1]

[1] Epilepsy Center, Cleveland Clinic, Cleveland, OH, USA
[2] Epilepsy Center, Clinic of Neurology CCS, Belgrade, Serbia
[3] Department of Neurology, Westmead Hospital, Westmead, NSW, Australia

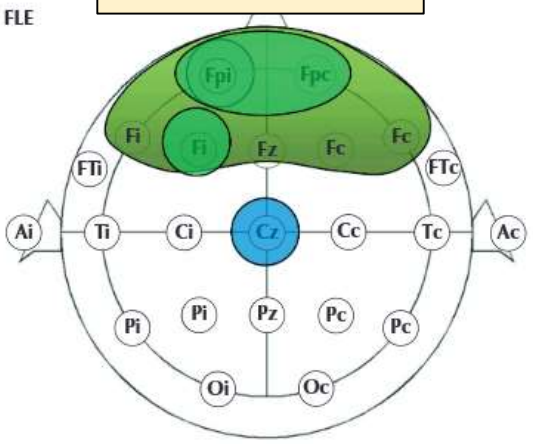
Parietal



Temporal



Frontal



Interictal discharges

Ristic AJ, et al. Epileptic disorder 2012;14(1):22-31

The localizing value of ictal EEG in focal epilepsy

N. Foldvary, DO; G. Klem, REEGT; J. Hammel, MS; W. Bingaman, MD; I. Najm, MD; and H. Lüders, MD, PhD

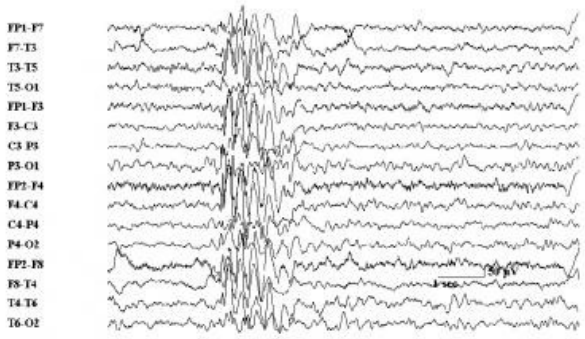
Localization	MTLE, n = 178	NTLE, n = 47	Temporal, n = 225	MFLE, n = 51	LFLE, n = 125	PLE, n = 56	OLE, n = 29	Extratemporal, n = 261	Total, n = 486
Correctly localized*	167 (93)†	35 (74)	202 (90)†	12 (24)	81 (65)	26 (46)	12 (41)	131 (50)	333 (69)
Correctly lateralized	1 (1)	10 (21)‡	11 (5)	1 (1)	8 (6)	—	2 (7)	11 (4)	22 (4)
Total incorrect	5 (3)	2 (4)	7 (3)	—	4 (3)	9 (16)	8 (28)	21 (8)	28 (6)
Mislocalized	5 (3)	—	5	—		2	2	4	9
Mislateralized	—	2 (4)	2	—	4 (3)	7	6	17	19
Generalized	5 (3)	—	5 (2)	38 (75)§	32 (26)	21 (38)	7 (24)	98 (38)§	103 (21)

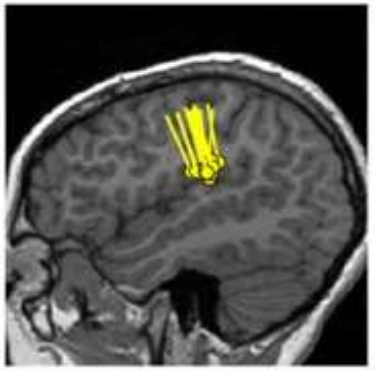
* Includes regional and focal patterns.
† Localized seizures more common in temporal lobe than extratemporal epilepsy, and in MTLE vs LFLE, MFLE, and OLE ($p < 0.001$).
‡ Lateralized seizures more common in NTLE ($p = 0.03$).
§ Generalized seizures more common in extratemporal epilepsy than temporal lobe epilepsy ($p < 0.001$) and in MFLE than the other subgroups ($p = 0.003$).

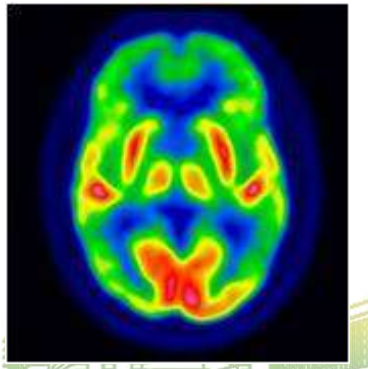
MTLE = mesial temporal lobe epilepsy; NTLE = neocortical temporal lobe epilepsy; MFLE = mesial frontal lobe epilepsy; LFLE = laterofrontal lobe epilepsy; PLE = parietal lobe epilepsy; OLE = occipital lobe epilepsy.

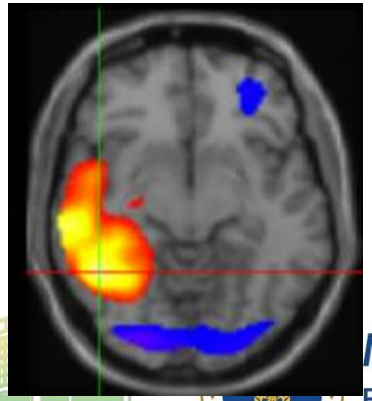
Foldvary N, et al. Neurology 2001;57:2002-8

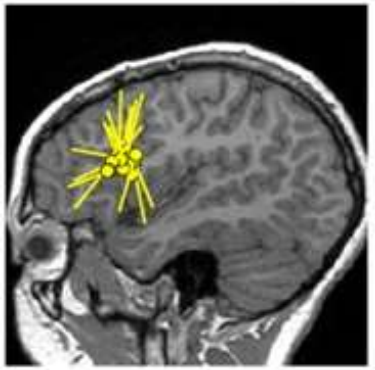
- These findings likely reflecting the richly entangled “connectivity” of the parietal lobe.





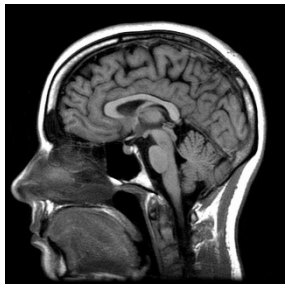






Imaging studies

MRI	No. (n = 26)
Normal	14
Cerebromalacia	4
Dysembryoplastic neuroepithelial tumor	1
Cortical dysplasia	1
Sulci widening	1
Calcification	1



Diagnostic modality	No.	Seizure free	Persistent seizure	p Value
Focal Lesion on MRI	26	9/14	3/12	0.062
Hypometabolism on PET	26	7/14	2/12	0.110
Focal hyperperfusion on Ictal SPECT	21	5/11	5/10	1.00
Localized ictal rhythm	26	5/14	5/12	1.00

Kim DW, et al. Epilepsia 2004;45:641-9

Parietal Lobe Epilepsy: The Semiology, Yield of Diagnostic Workup, and Surgical Outcome

*Dong Wook Kim, *Sang Kun Lee, ‡Chang-Ho Yun, *Kwang-Ki Kim, †Dong Soo Lee, §Chun-Kee Chung, and ||Kee-Hyun Chang

*Departments of *Neurology, †Nuclear Medicine, §Neurosurgery,and ||Diagnostic Radiology, Seoul National University College of Medicine, Seoul; and ‡Department of Neurology, Inha University College of Medicine, Incheon, Korea*

- Favorable surgical outcome: 22/26 pts
- 14/22 pts were seizure-free
- Favorable outcome:
  - Lesional MRI
  - The concordance rate of the various diagnostic modalities

Kim DW, et al. Epilepsia 2004;45:641-9