Invasive EEG evaluation

Indications and Methods

Juan C. Bulacio MD

Epilepsy Center

Neurological Institute

Cleveland Clinic

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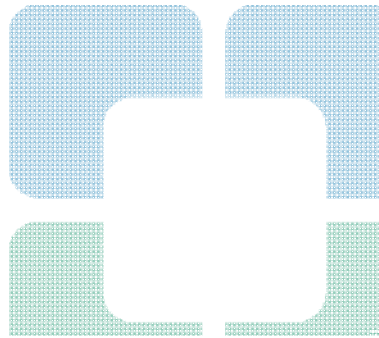
Outline

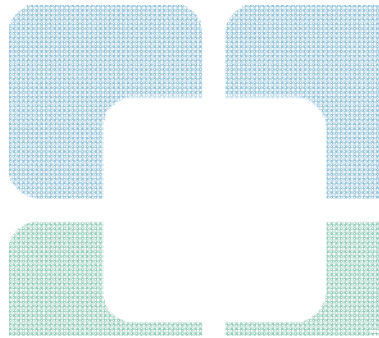
- Rationale for the use of invasive evaluation techniques
- Indications of invasive evaluations in epilepsy surgery
- Methods
  - Acute intraoperative ECOG
  - Subdural and Depth electrodes
  - Stereoelectroencephalography SEEG
- Limitations and complications
- Conclusions



Rationale for the use of invasive evaluation

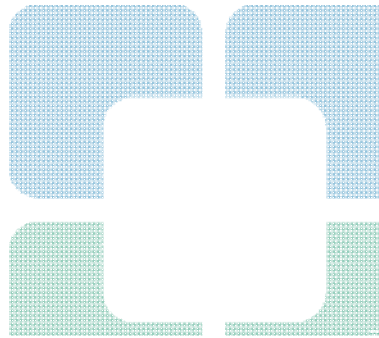
- Noninvasive testing at times fails to provide adequate information to plan surgery, where the central question is about identification and localization of the “epileptogenic zone” (EZ) and its relation with cortical and subcortical eloquent cortex.

- And it is reasonable to believe that further information will likely lead to surgical resection.



Indications of invasive evaluation in Epilepsy Surgery

- MRI-negative cases
- Electroclinical and MRI data discordance
- Overlap with eloquent cortex
  - Localize motor, sensory and language function



MRI-negative

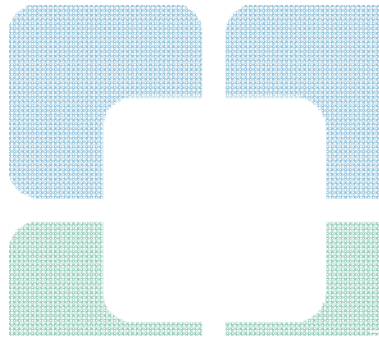
Illustrative case

- Adult, right handed
- Aura: mixture of “weird feelings”: (fuzzy feeling in her head, strange feeling in the stomach, floating sensation), it will progress to visual hallucinations such as “everything becomes black or blue color”.

  Aura followed by repetitive chewing/swallowing.

  During the seizure patient has naming problem, word finding difficulty, unable to repeat sentence fluently while maintaining awareness (following verbal command).

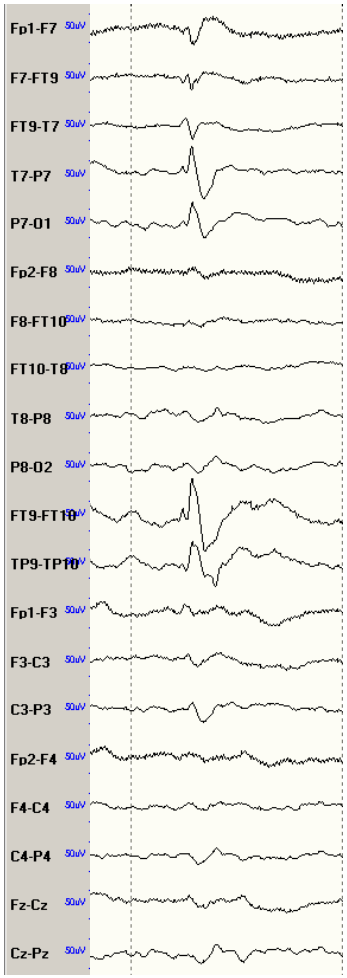
  Postictally, can not get words out while knowing what she wanted to say.



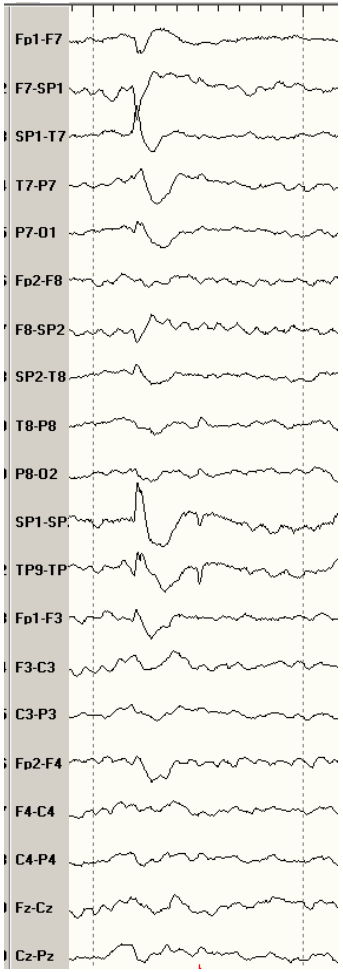
MRI-negative

Illustrative case

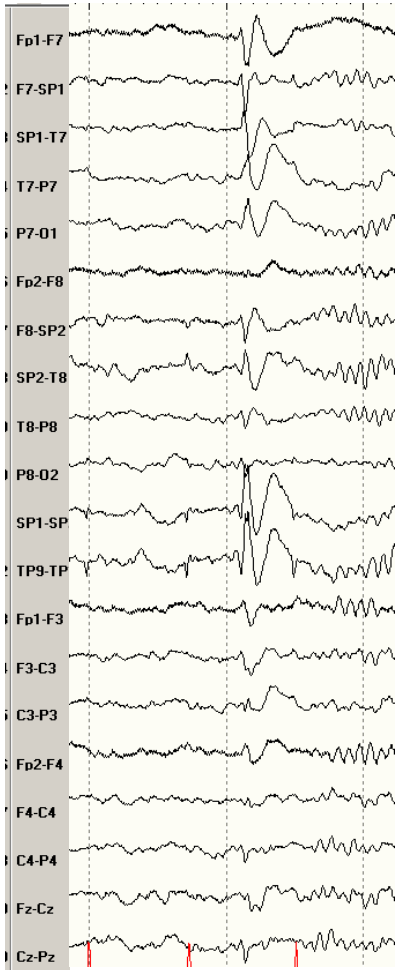
T7/T9/TP7



Sp1/T9/FT9/F9

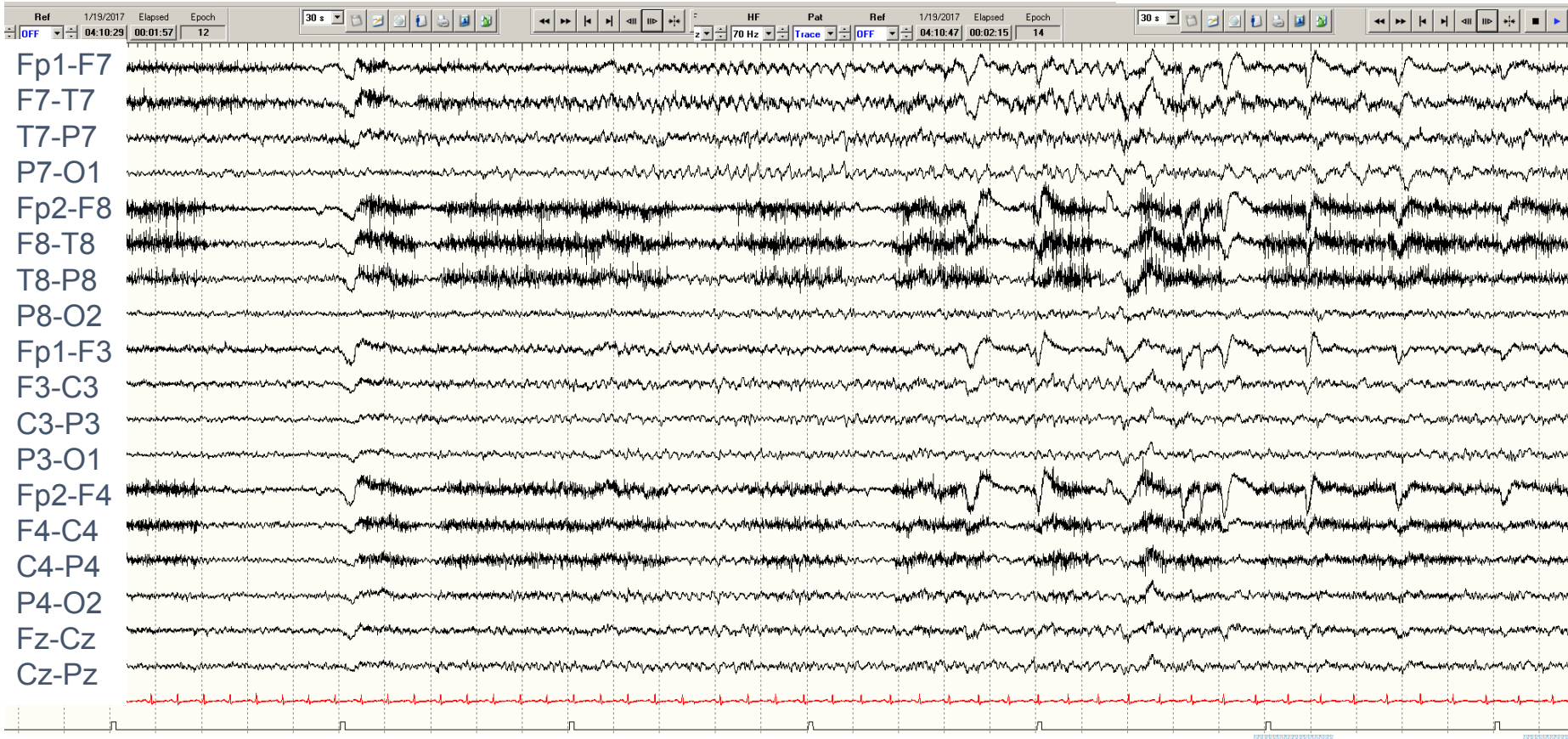


Initial frontal negativity f/by SP1



MRI-negative

Illustrative case

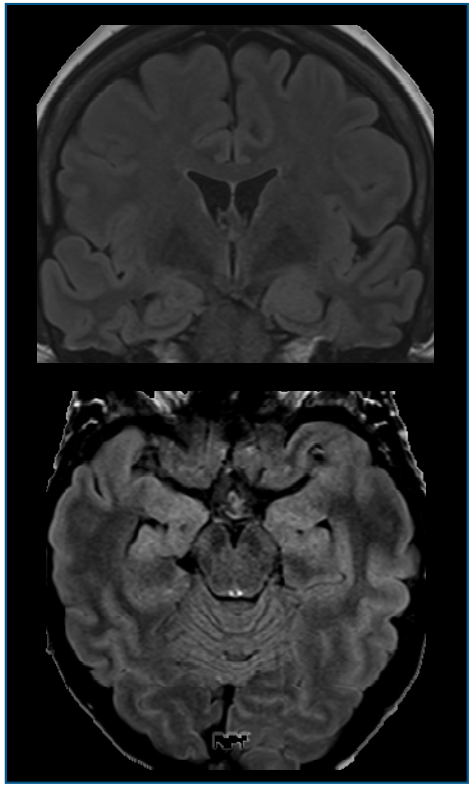


EEG seizure: Regional bilateral posterior? -> Left frontotemporal

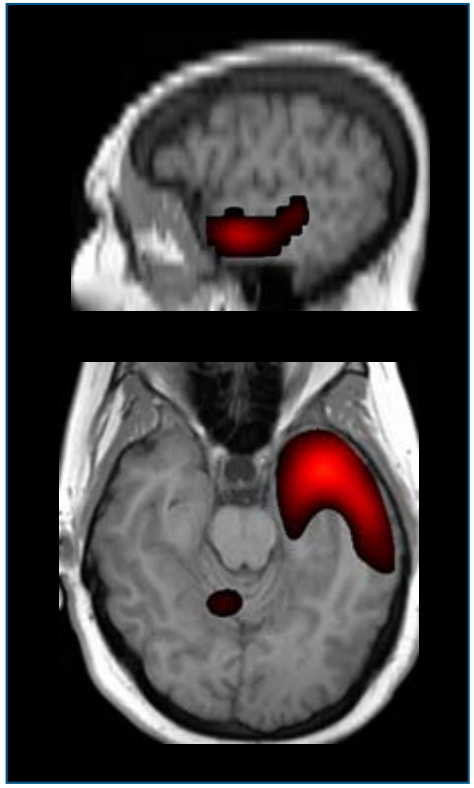
Patient complained of visual aura (color)

MRI-negative

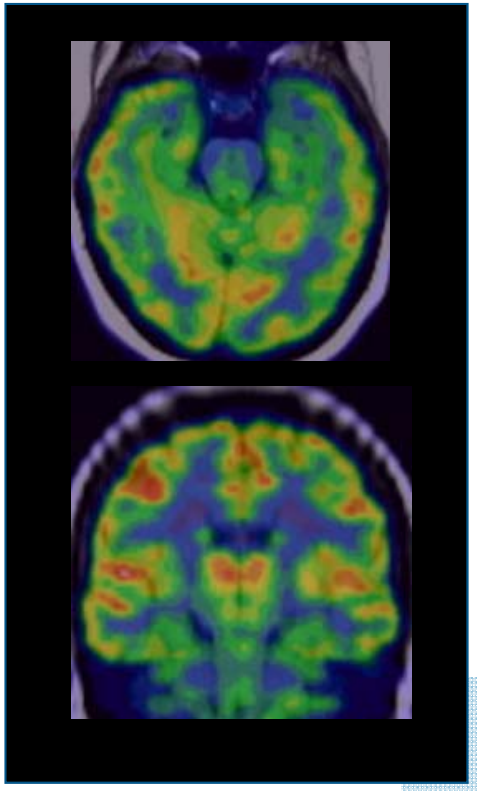
illustrative case



3T MRI: unremarkable

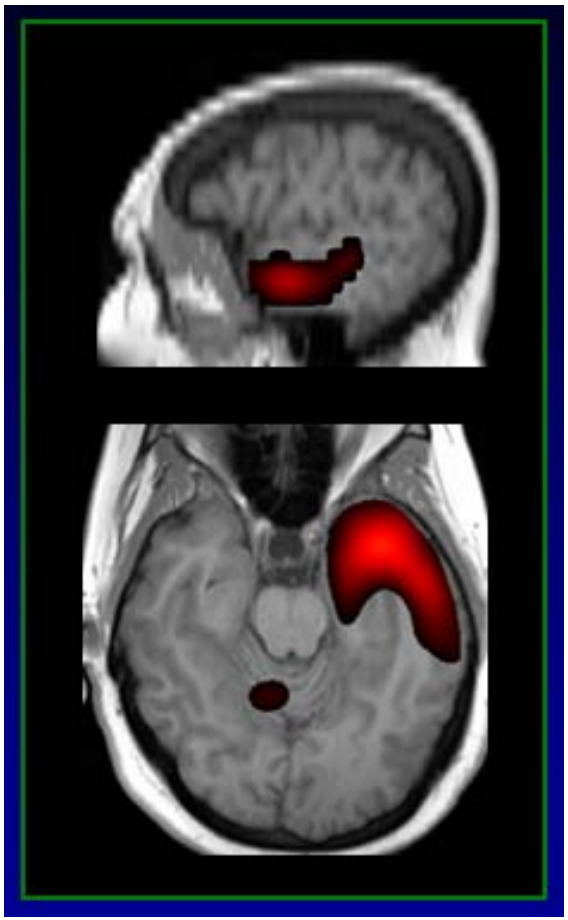


-Left mid superior temporal
-Left Posterior basal temporal
-Right basal occipital region
-Bilateral inferior mesial occipital



-Left anterior Temporal
-Left Posterior Basal Temporal
-Left Temporo-Frontal operculum
-Lateral Frontal

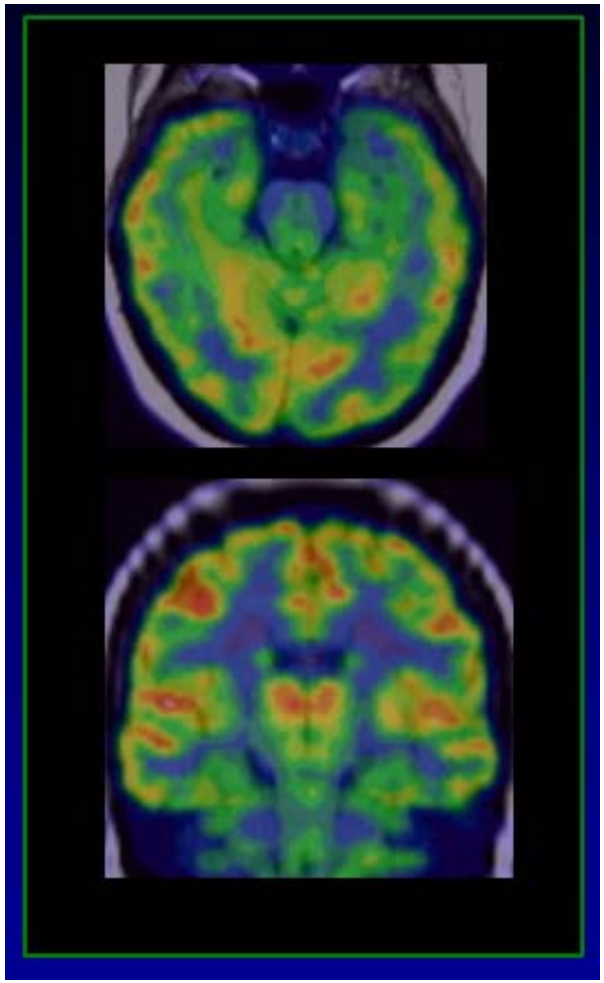
MRI-negative



SISCOM has moderate sensitivity in localizing the epileptogenic zone and can provide complimentary information when MRI is negative.

Chen T. et al; The role of SISCOM in preoperative evaluation for patients with epilepsy surgery. Seizure, 2016 (41):43-50

MRI-negative



- Surgical outcomes of MRI−, PET+ TLE patients are similar to those of MTS patients.
- HM on PET is a good predictor for surgical outcome in patients with normal MRI
- More than 2/3 of MRI−, PET+ patients with TLE are seizure-free.

Capraz IY et al, Seizure 2015

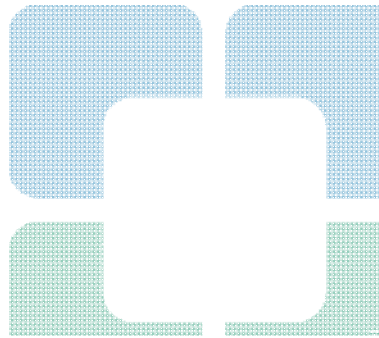
Lo-Pinto-Khoury C et al, Epilepsia 2012

Key points

- The lack of abnormalities on brain MRI is not per se an indication of intracranial evaluation.
- Other clinical neurophysiologic and neuroimaging modalities can provide evidence of localization-related epilepsy, including clinical semiology combined with video-EEG, (PET), and (SPECT).
- However, when brain MRI is negative and other modalities are discordant, intracranial evaluations, most often SEEG, are required.

Indications of invasive evaluation in Epilepsy Surgery

- MRI-negative cases
- Electroclinical and MRI data discordance
- Overlap with eloquent cortex
  - Localize motor, sensory and language function



Electroclinical and MRI data discordance

- Seizure history:
  - First seizure: 3 years old prolonged GTC (Left Todd´s paresis)
  - Seizure-free till 15 years of
  - Frequency: 1 every 6 weeks

- Recorded (single seizure type):

  Aura: unique smell (burnt chocolate)

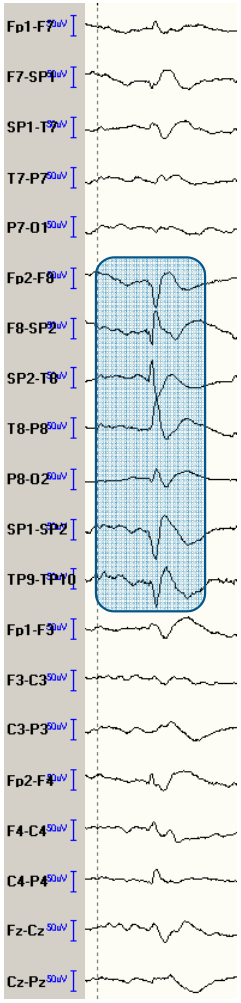
  Preserved awareness→ ictal speech (“It´s going to be OK”) → chewing/swallowing →grabbing, rubbing hands →rocking movements→ unresponsiveness → LEFT turning→ GTC

  All seizures with autonomic features

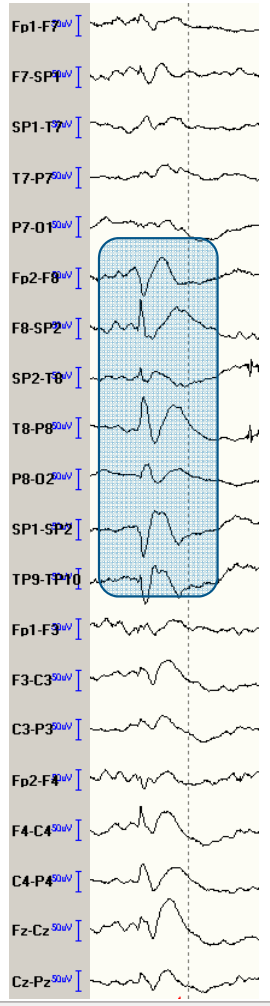
  Duration: 30 seconds to 5 min

- Historical: Prolonged seizures

SW right antero-mesial and fronto-temporal

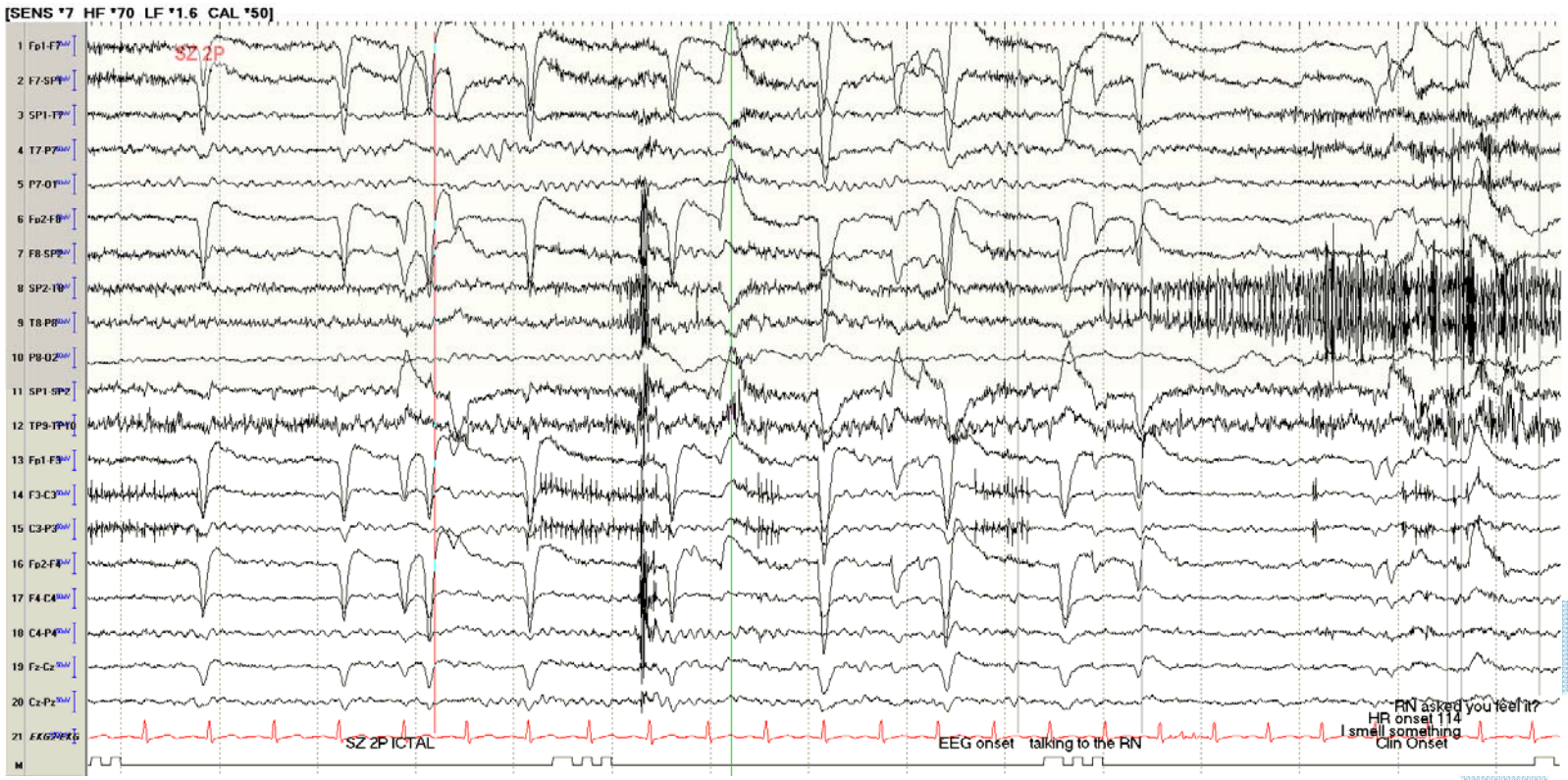


Sp2/FT10/F10/T10→FT8/F8/T8



FT8/F8/FT10>AF8>F10/FC6

Electroclinical and MRI data discordance



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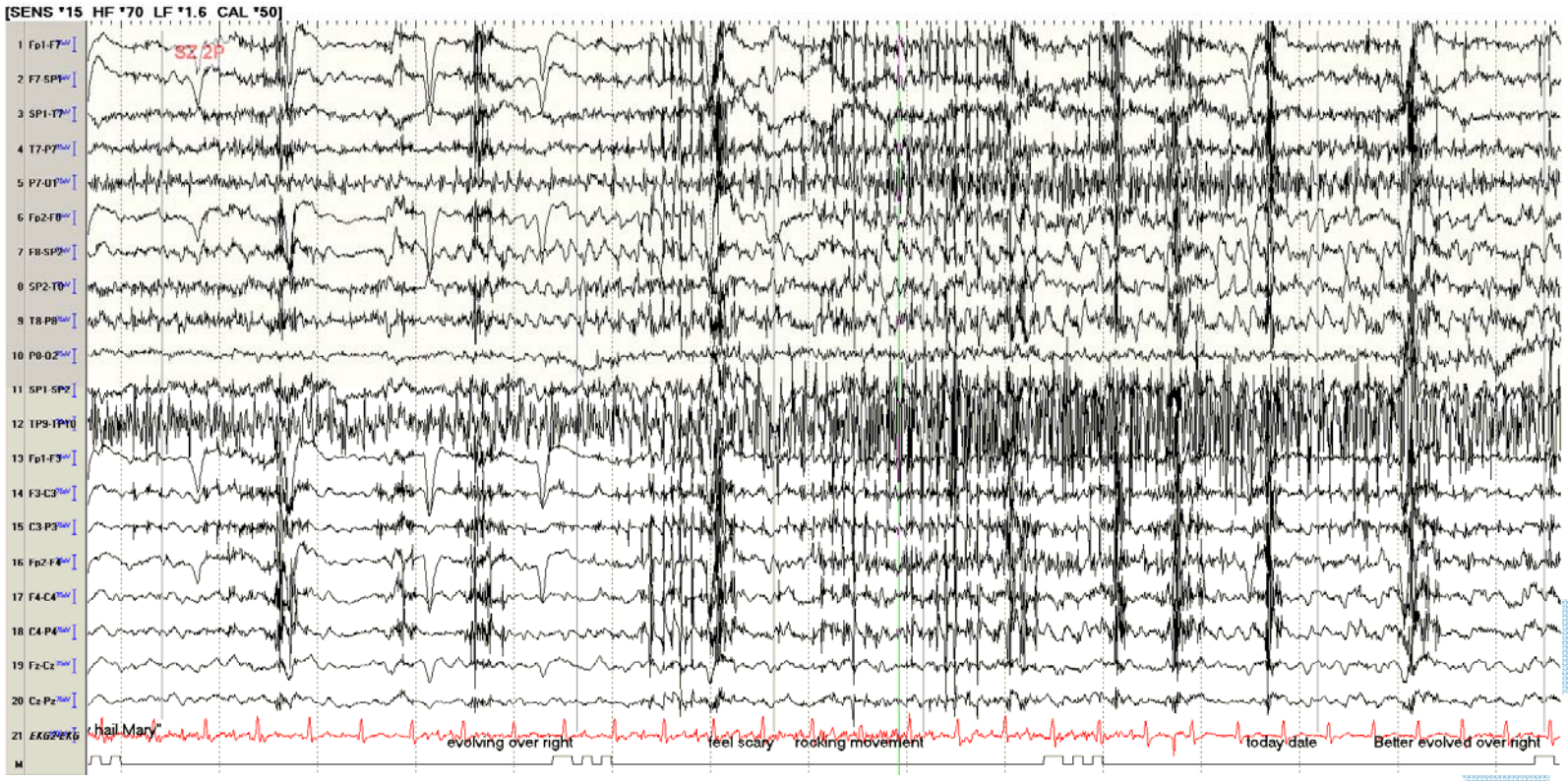

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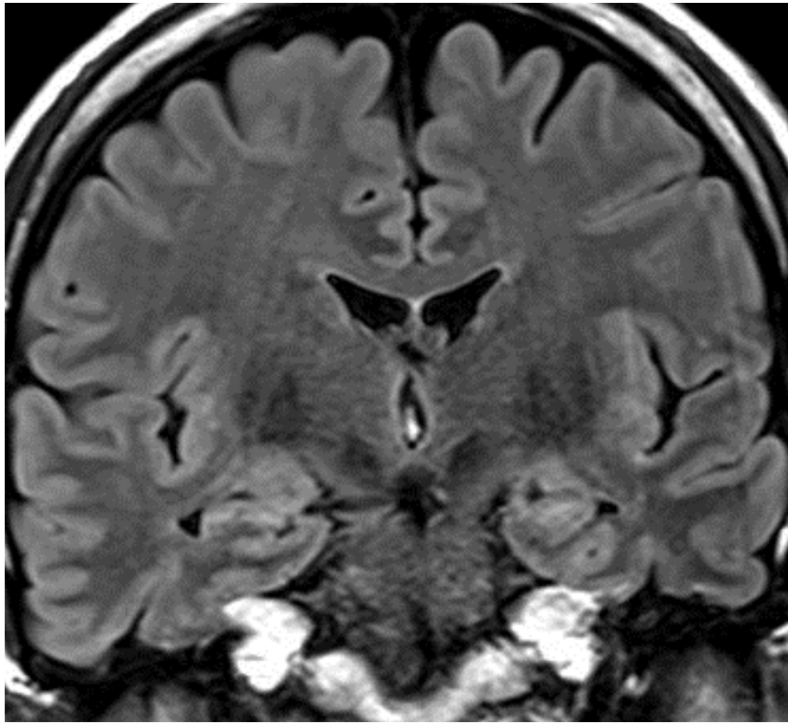
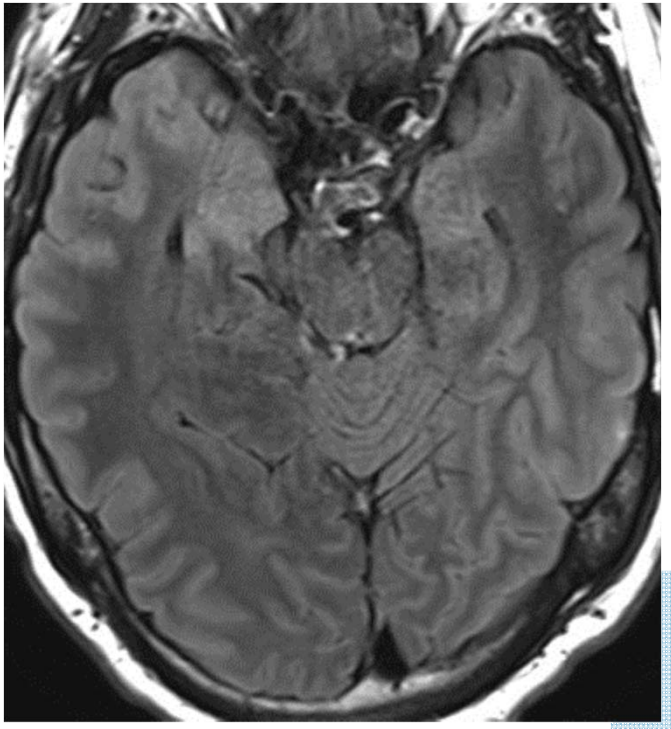
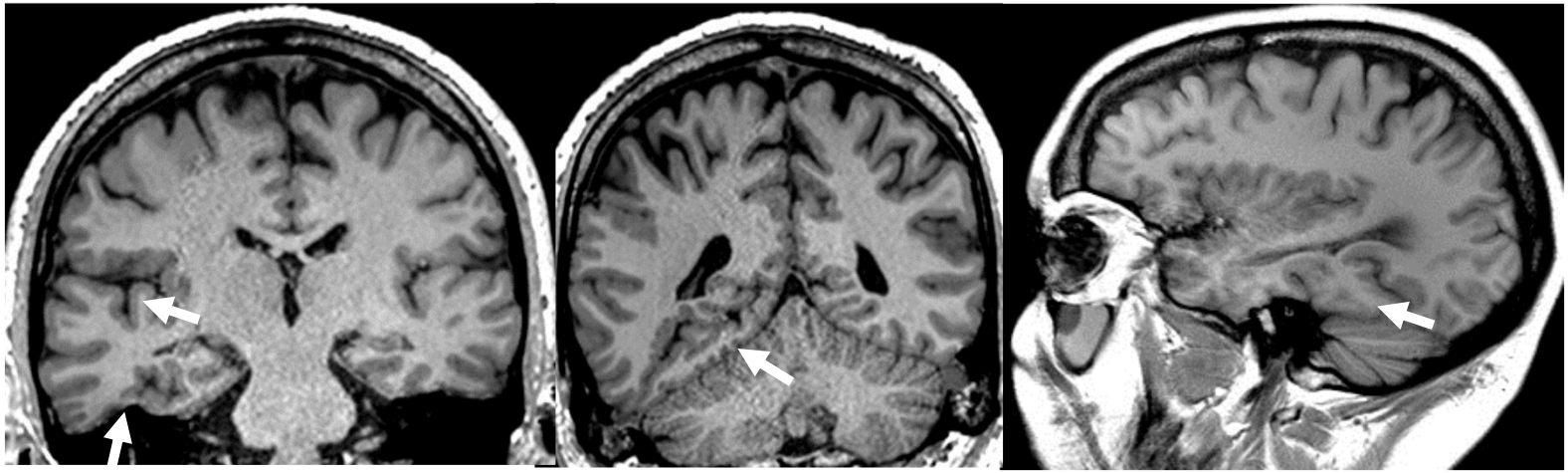




Increased signal in the right hippocampus

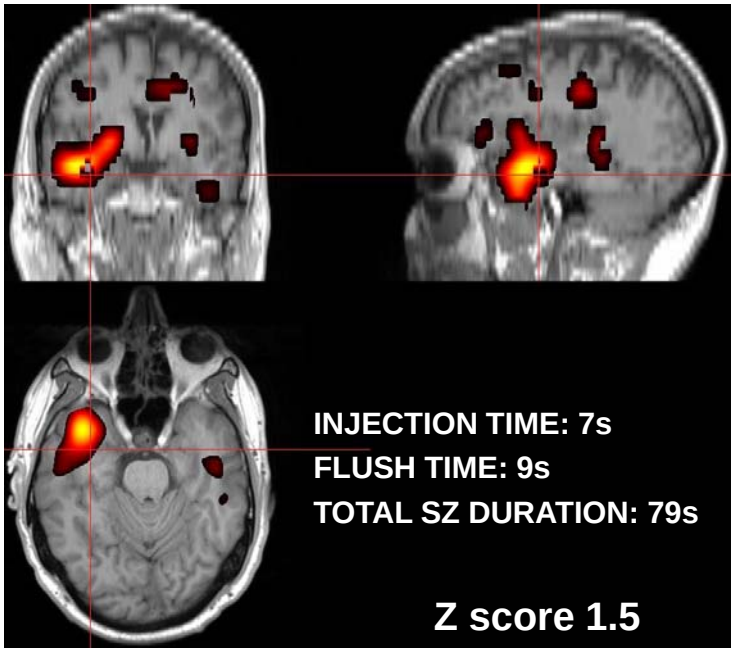
Electroclinical and MRI data discordance



Right hemispheric polymicrogyria with multiple clefts involving:

-Right parietal and temporal opercular areas
-Right dorsal insular cortex
-Right temporal/occipital region (with amygdala/hippocampal dysmorphism) and the most of the fusiform gyrus.

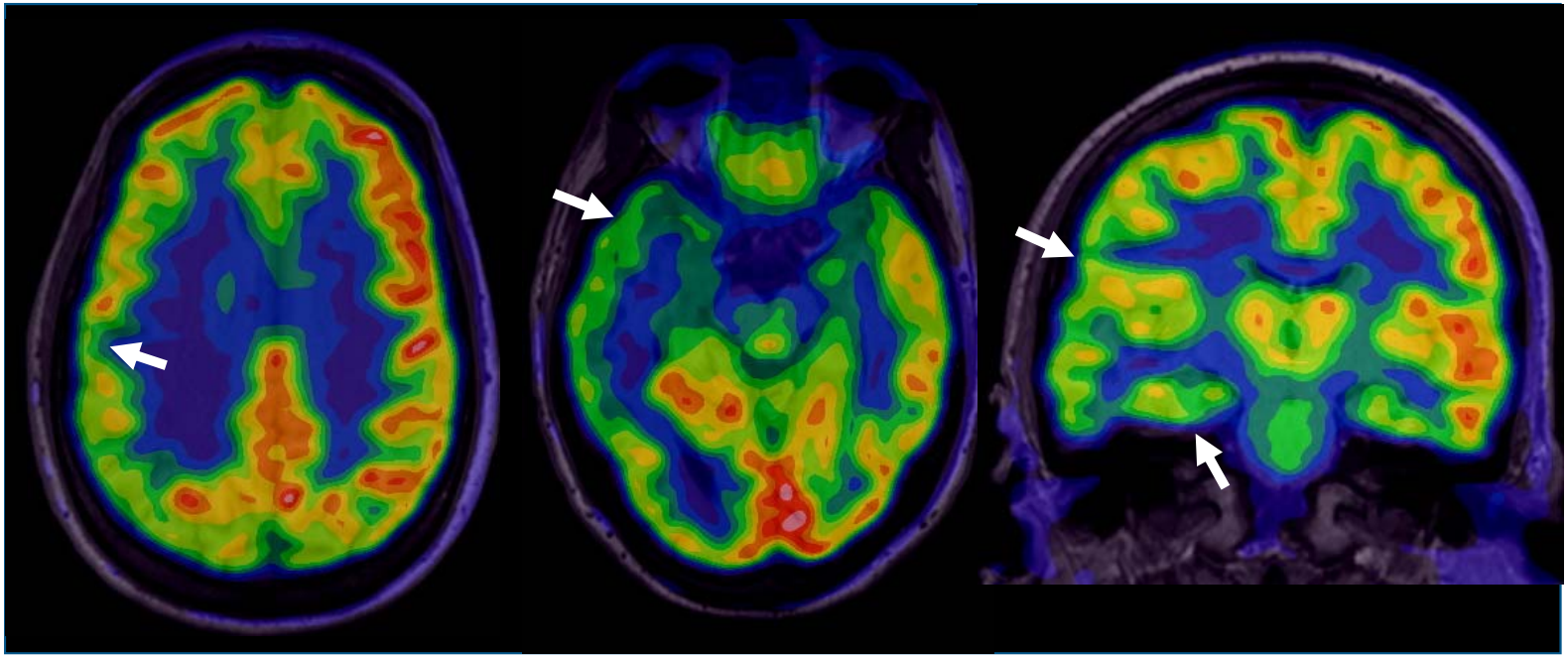
Electroclinical and MRI data discordance



Sz 2P: Olfactory aura →Autonomic Sz → Automotor sz → Hypermotor sz

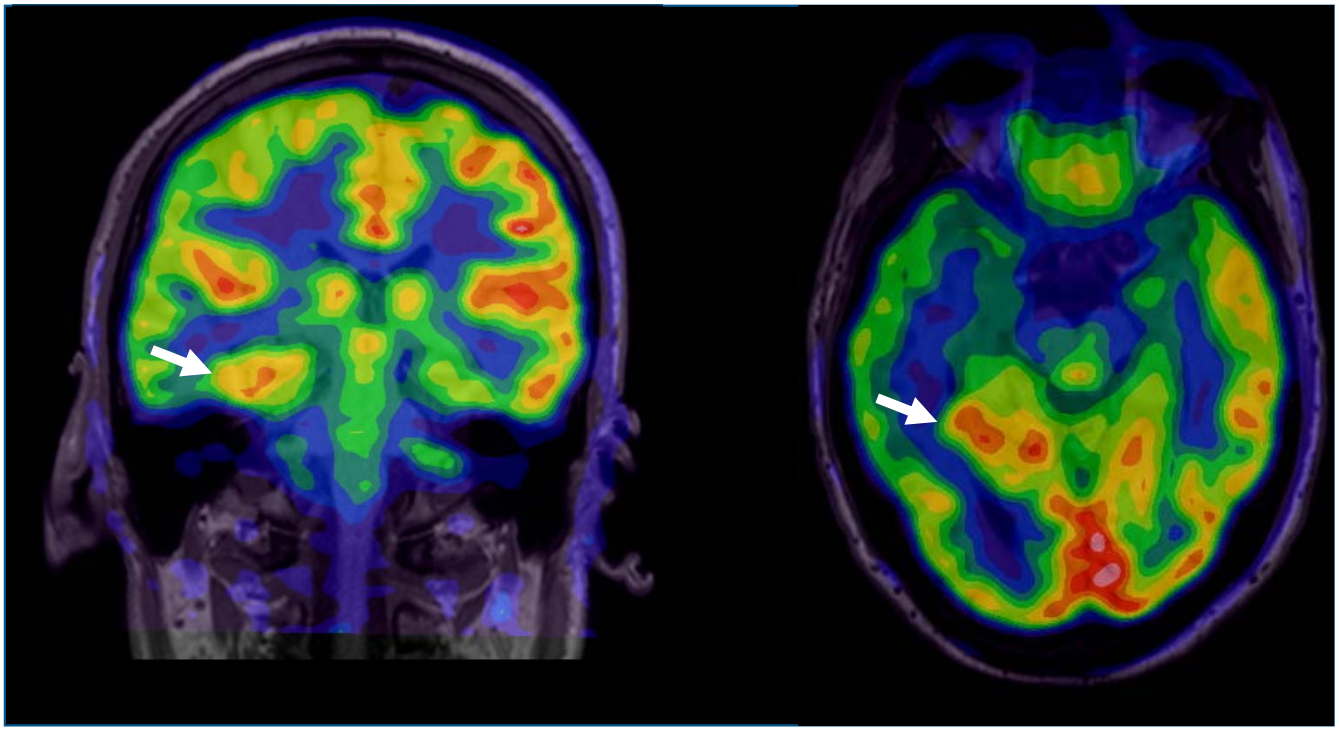
Right anterior Temporal region
Right Ventral Insular region

Electroclinical and MRI data discordance



Diffuse cortical hypometabolysm involving right hemisphere, more pronounced in the right peri-opercular region, right anterior temporal, right mid to posterior basal temporal

Electroclinical and MRI data discordance



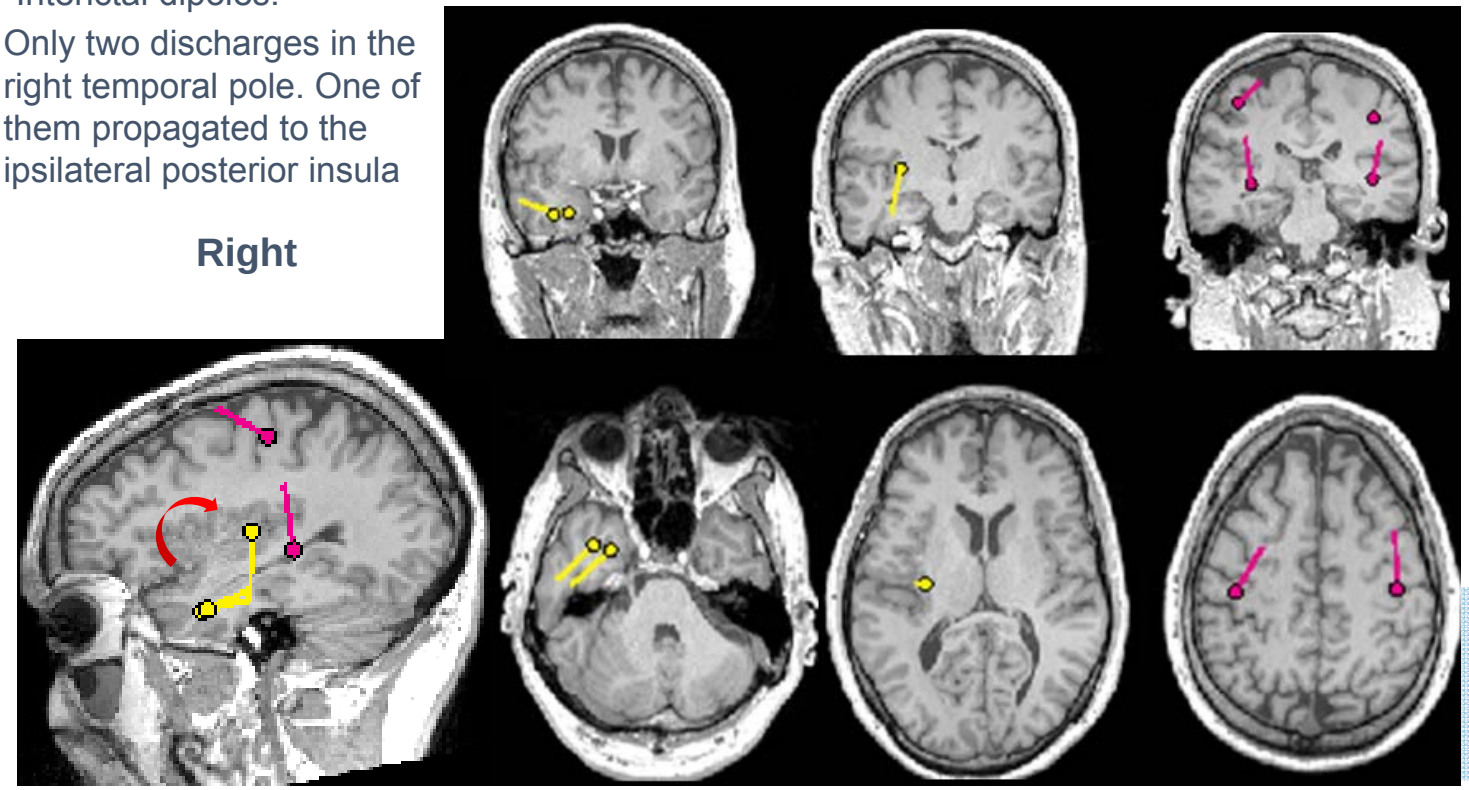
Hypermetabolism involving the mesial basal temporo-occipital PMG

Electroclinical and MRI data discordance

•Interictal dipoles:

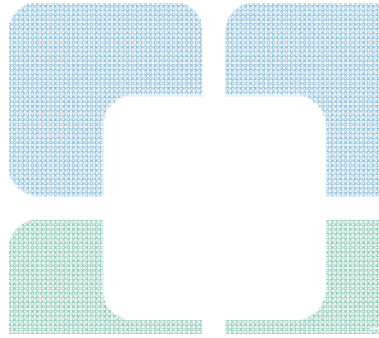
Only two discharges in the right temporal pole. One of them propagated to the ipsilateral posterior insula

Right



Key Points

- Two or more anatomical lesions, and the location of at least one is discordant with the electroclinical hypothesis, or both lesions are located within the same functional network and it is unclear if one (or both) of them is (are) epileptic.
- Cases of deeply seated brain lesions (PVNH and BOS FCD).



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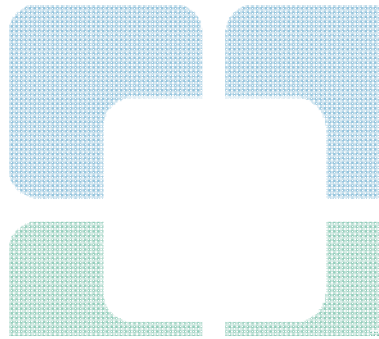
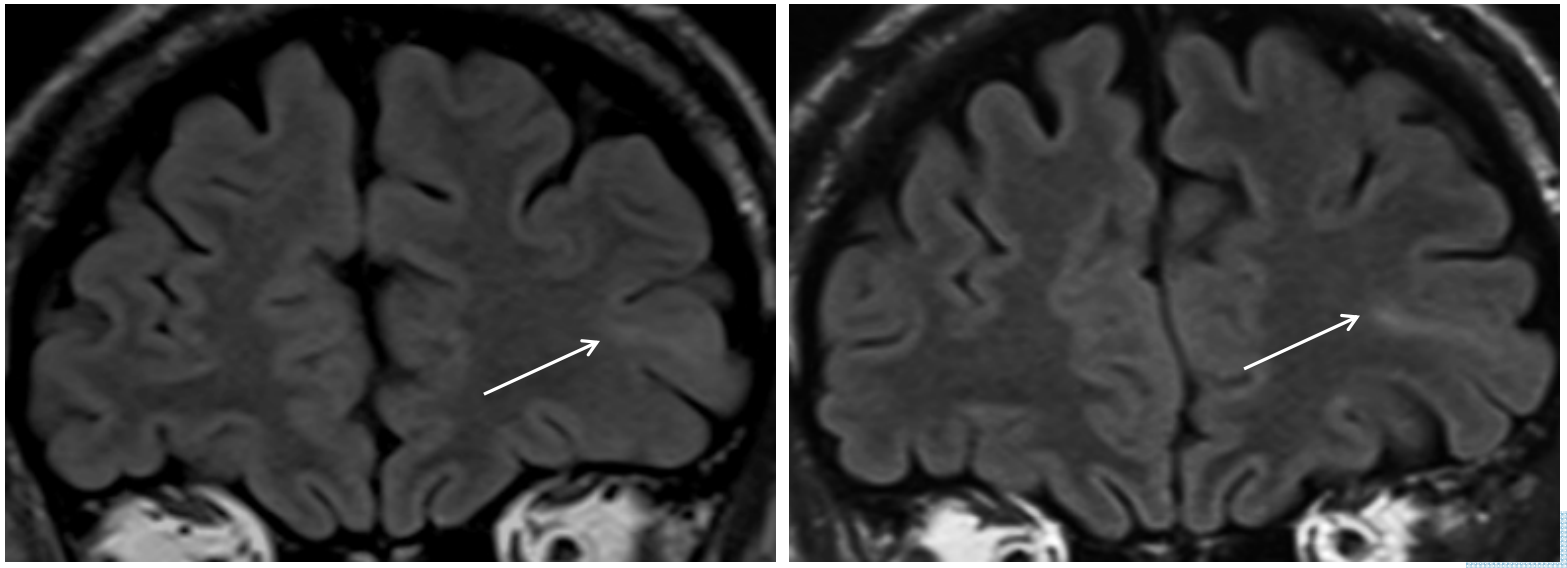
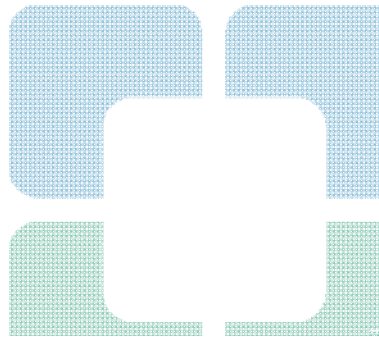


Transmantle Malformation of Cortical Development



Overlap with eloquent cortex

- The generated hypothesis (MRI -/+) involves potentially highly eloquent cortex.
- The identification of the EZ, mapping of its extent, and its relationship with potentially eloquent cortex are not typically resolved in these cases.

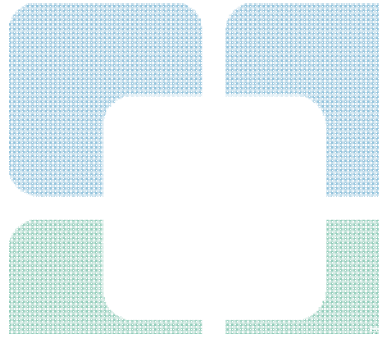


Overlap with eloquent cortex

Illustrative case

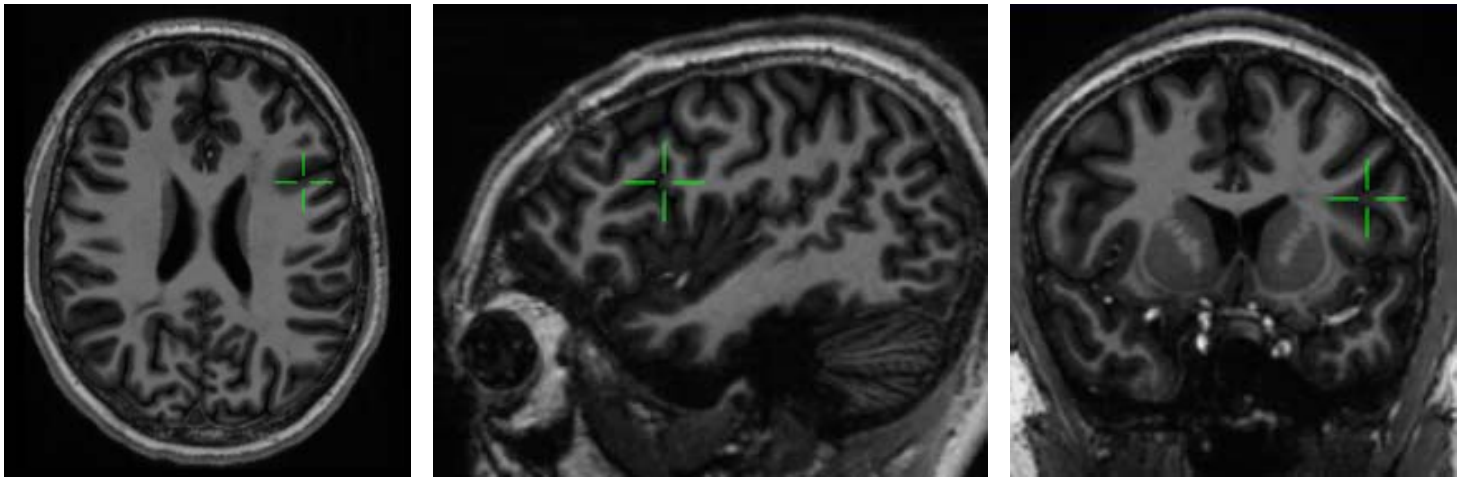
- Never alerts about the seizure
  - “tingling sensation” inside the head
  - “difficulties to talk”

- Seizure semiology:
  - Axial stiffening with prominent tonic bilateral facial grimace
  - Upper body mild flexion, proximal stiffening of the arms and right arm dystonic posturing
  - Then moves semi-purposefully at the onset of tonic phase, have axial and hand stereotypies
  - Toward the end of the seizure may start follow the commands, but does not respond verbally



Overlap with eloquent cortex

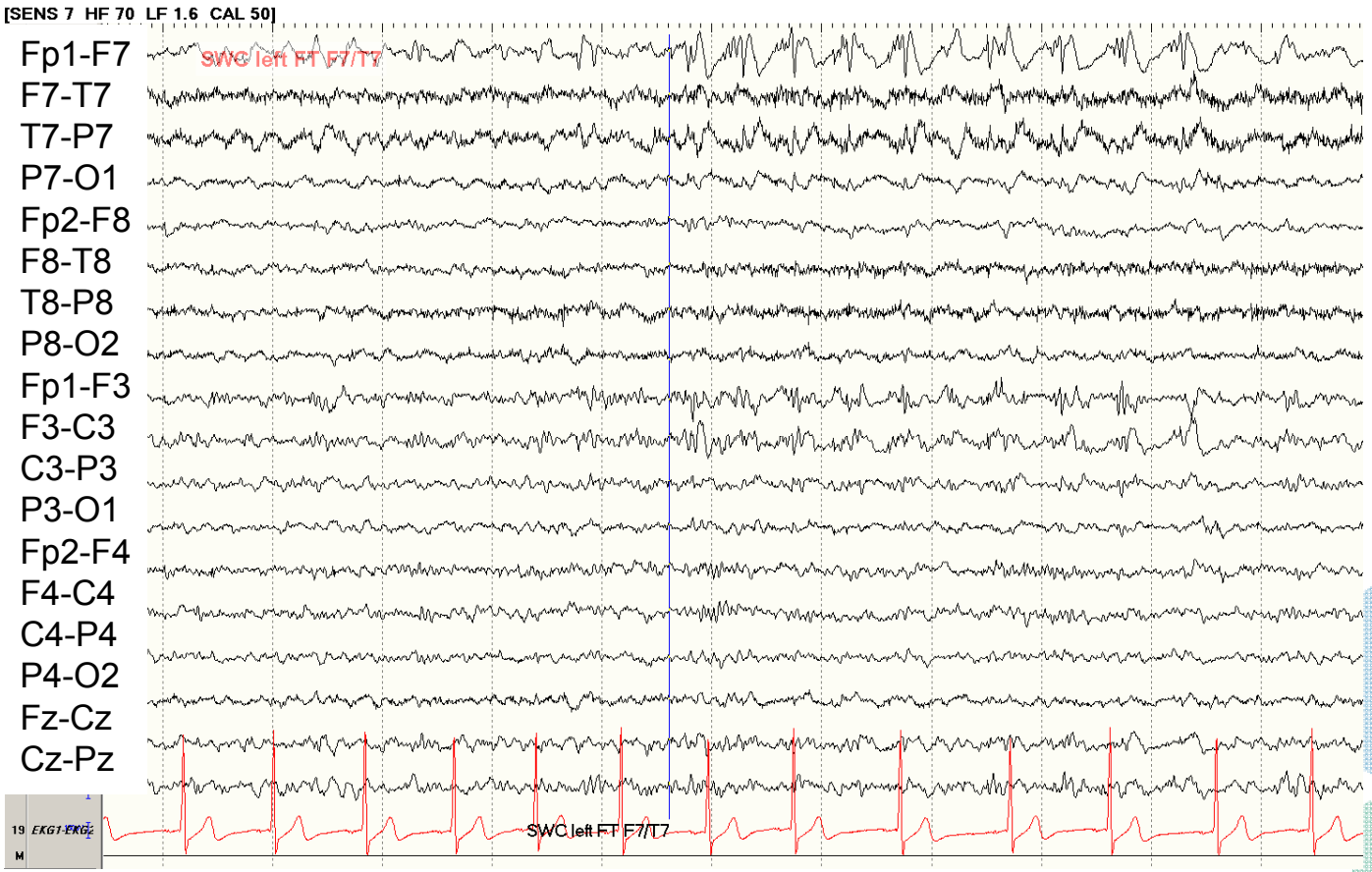
Illustrative case



Overlap with eloquent cortex

Illustrative case

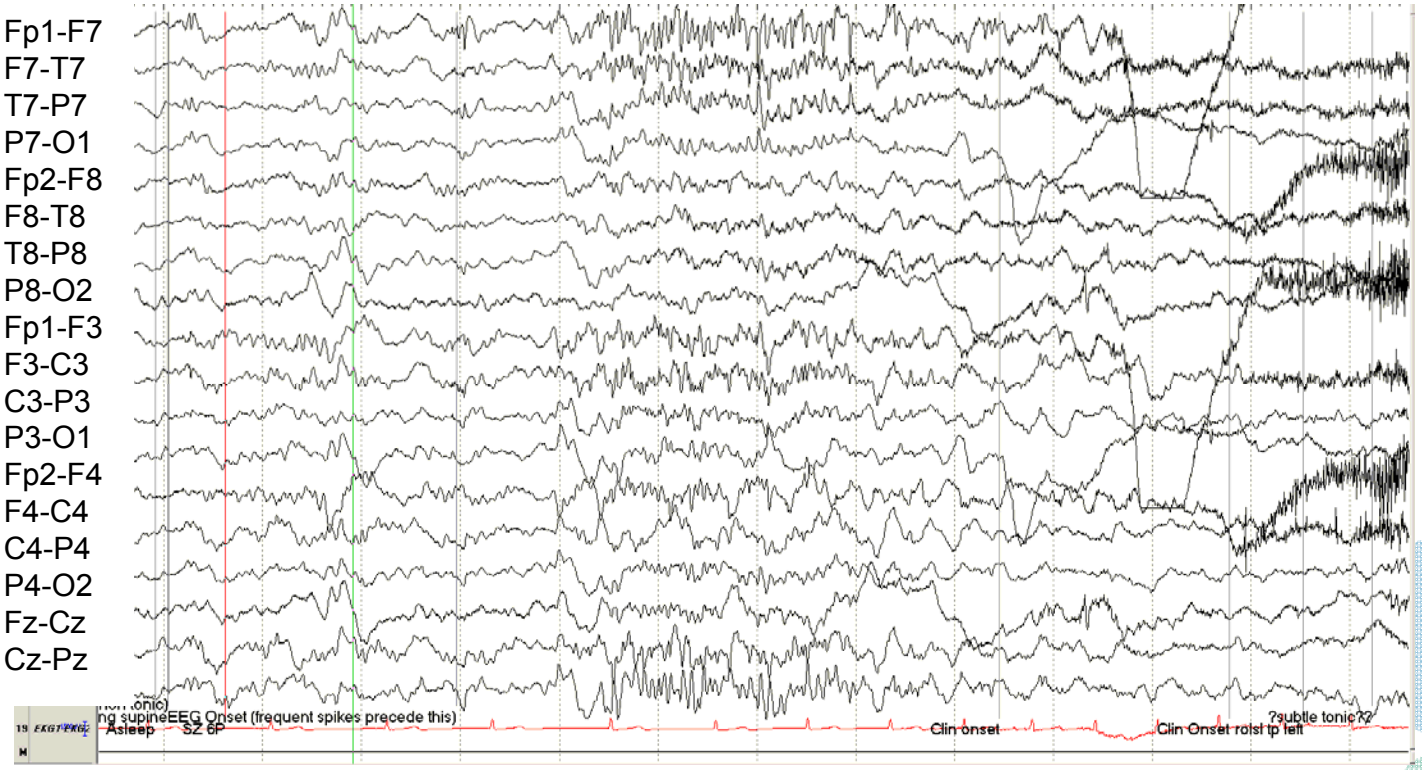
Interictal EEG



Overlap with eloquent cortex

Illustrative case

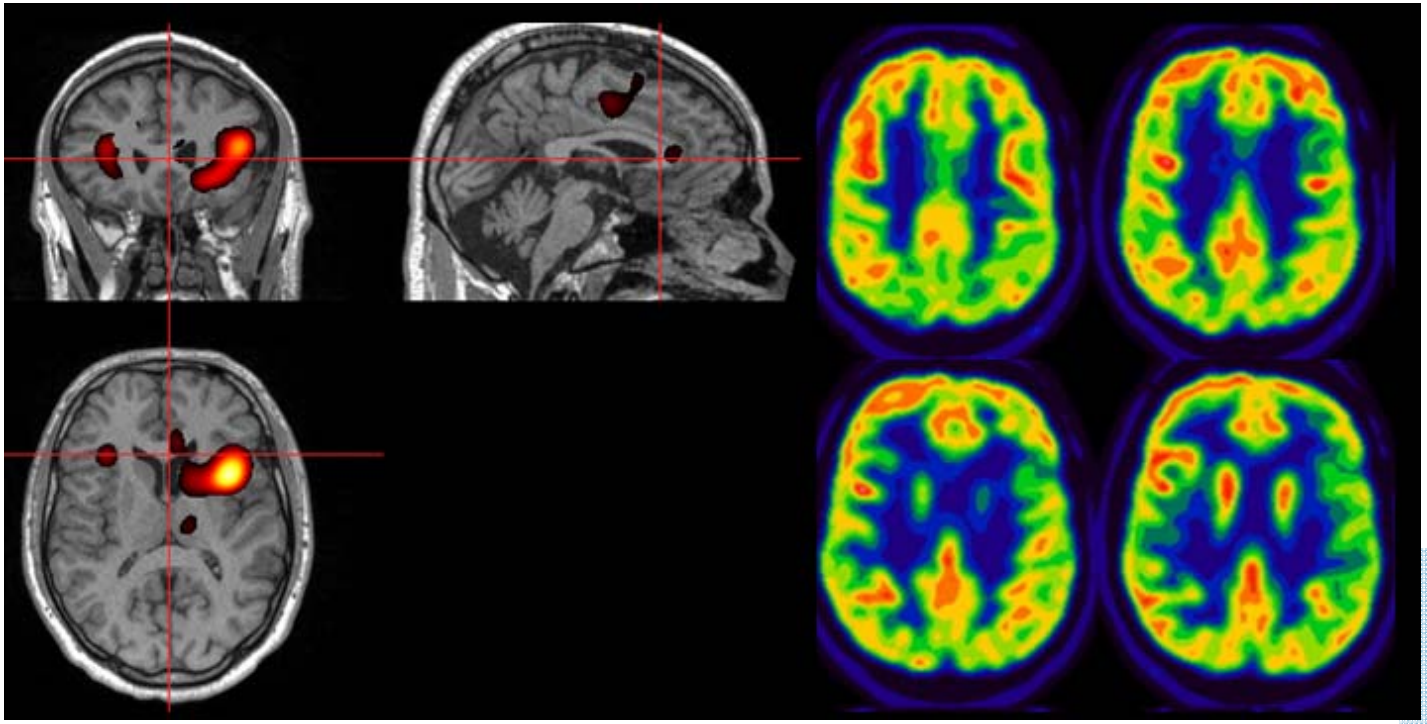
Ictal EEG



Overlap with eloquent cortex

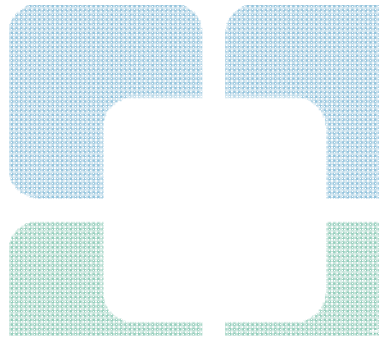
Illustrative case

SPECT PET

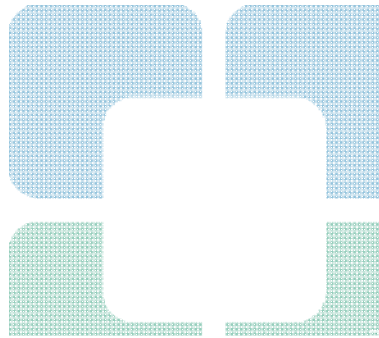


Key points

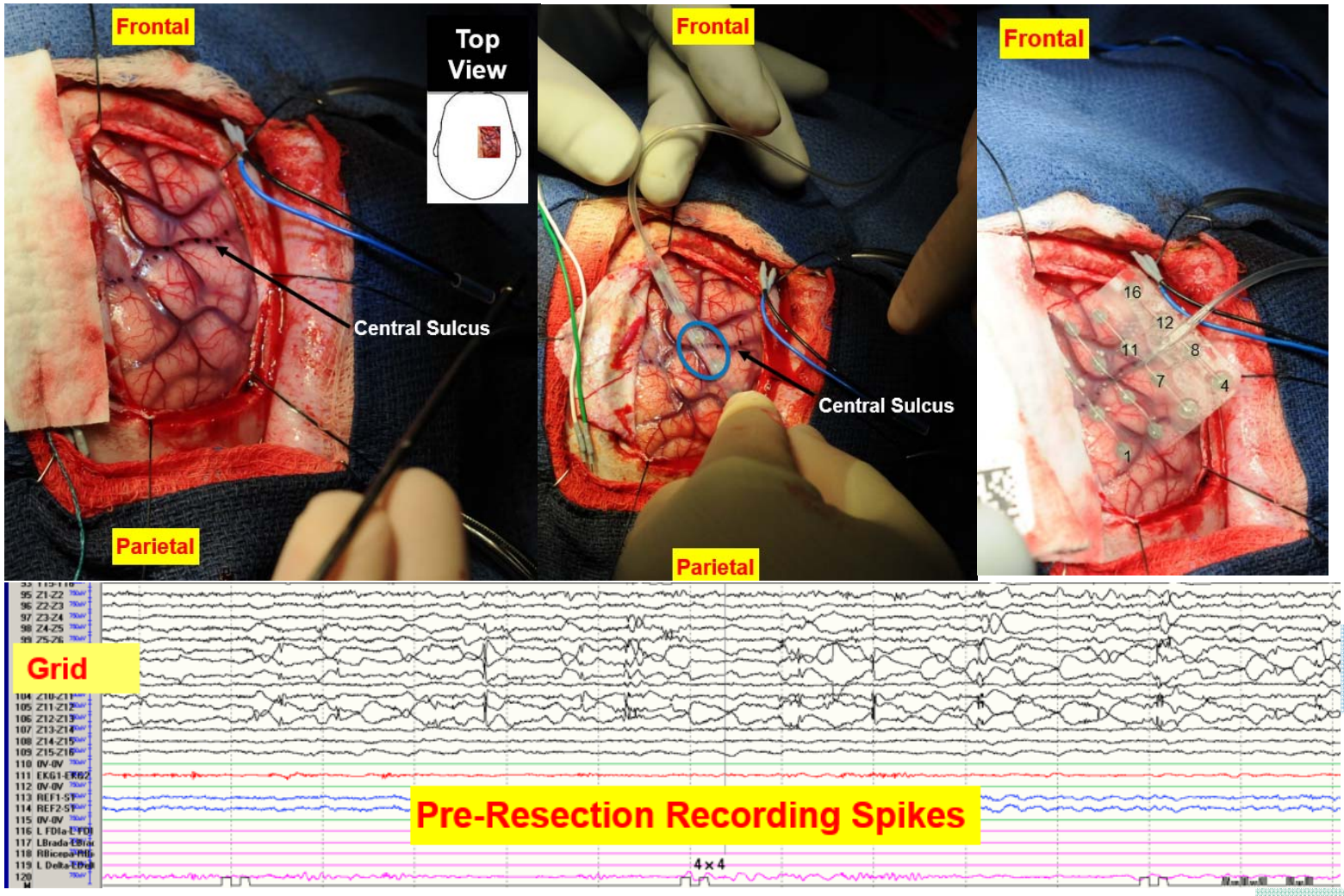
- In this situation, the management approach is individualized according to the patient's condition.
- IntraOp-Electrocorticography (EcoG).
- SDG/depth electrodes, given their superior ability for mapping eloquent function.



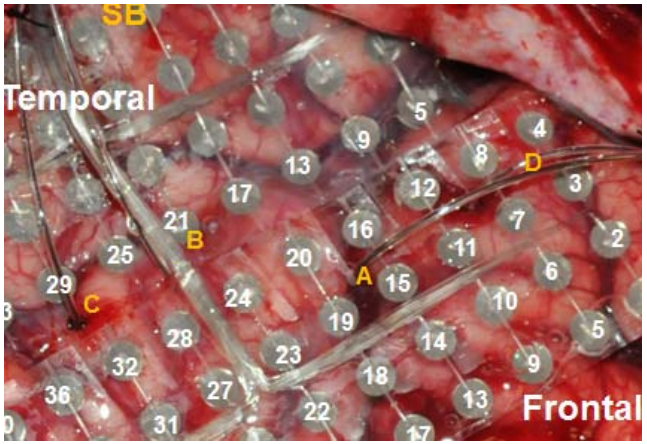
Intracranial Evaluations Methods

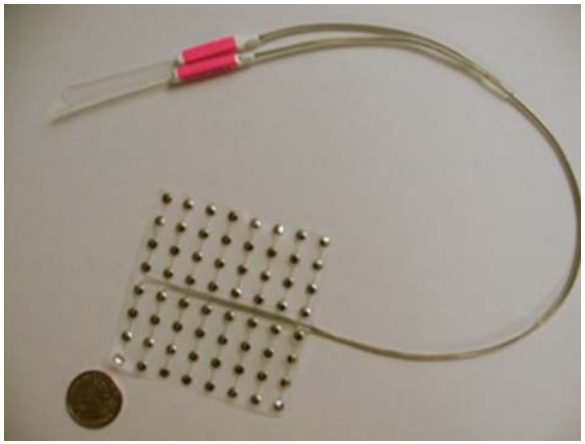


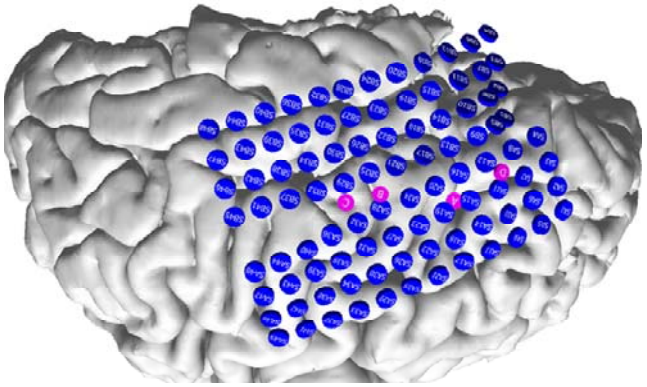
Acute intraoperative ECOG

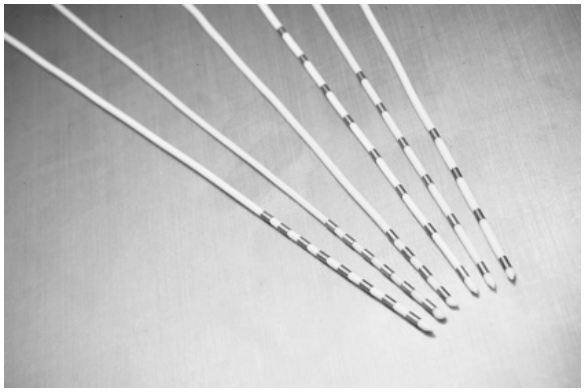


Subdural Grid and Depth electrodes

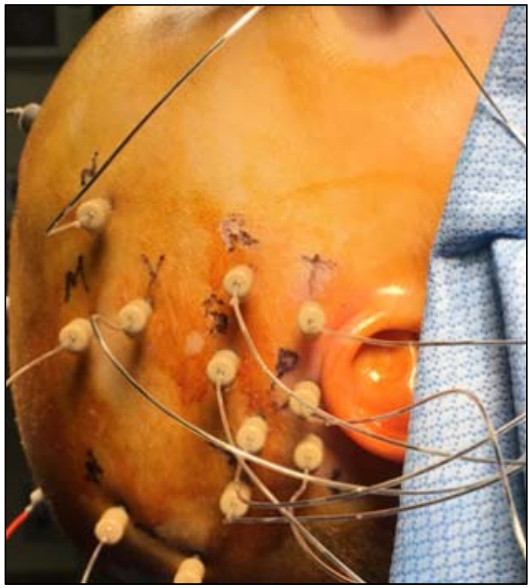


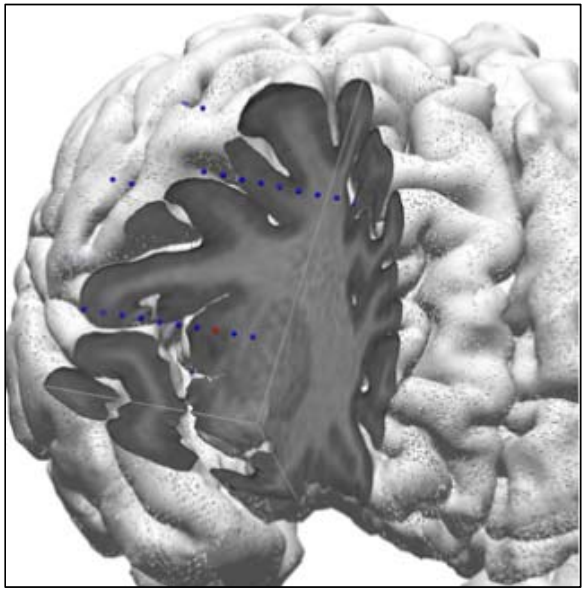


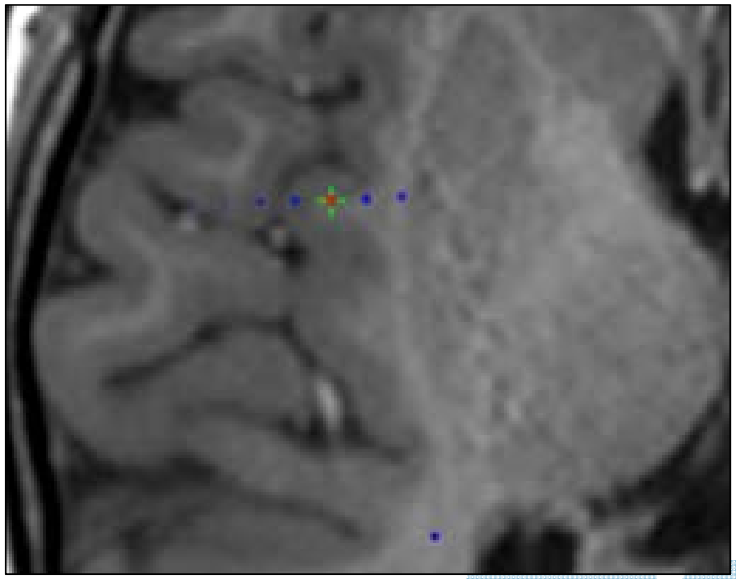




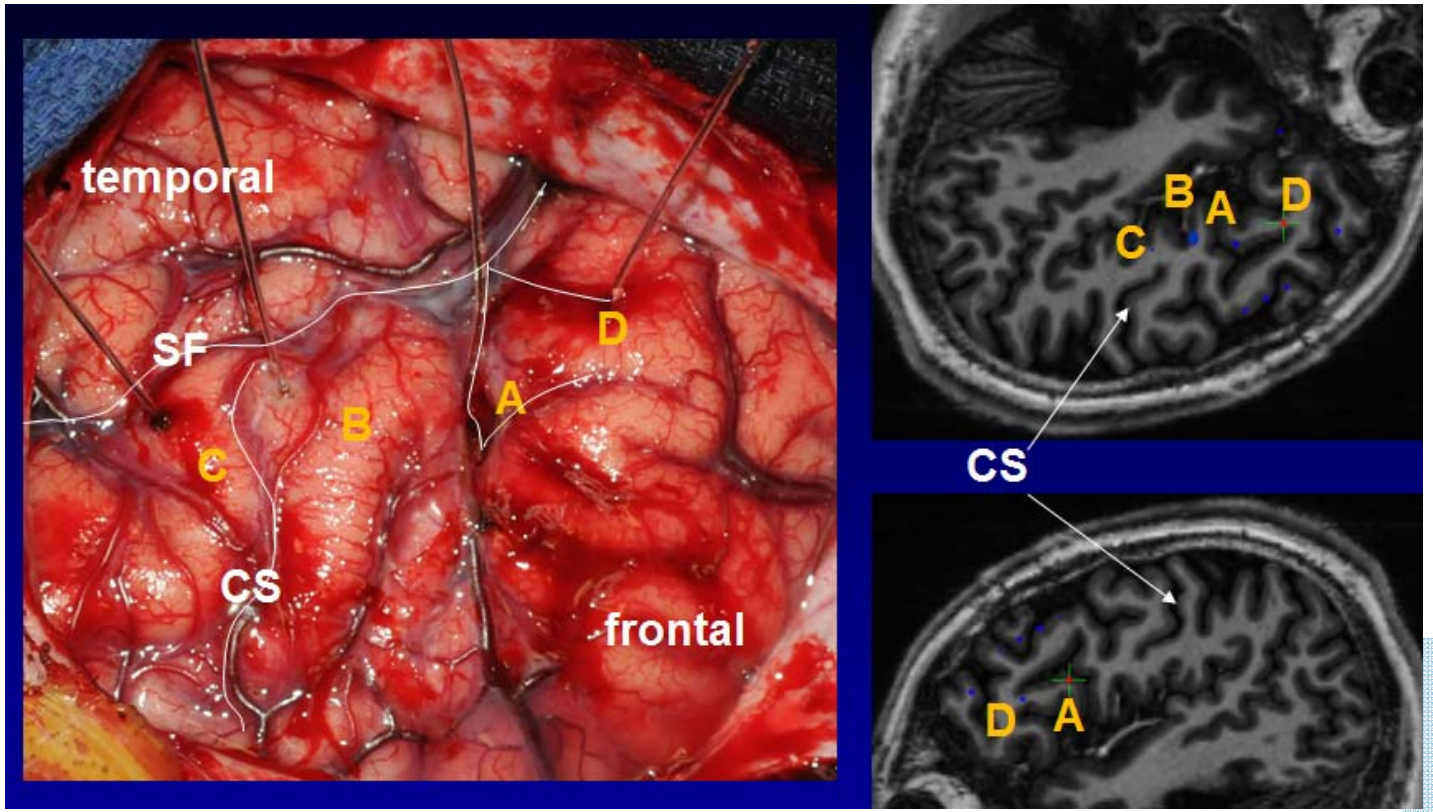
Stereoelectroencephalography -SEEG-







Subdural Grid and Depth electrodes



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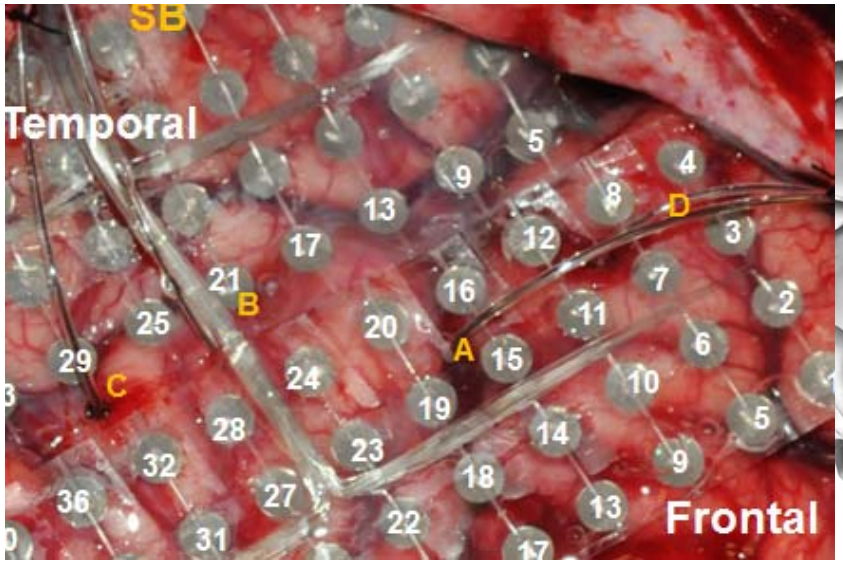
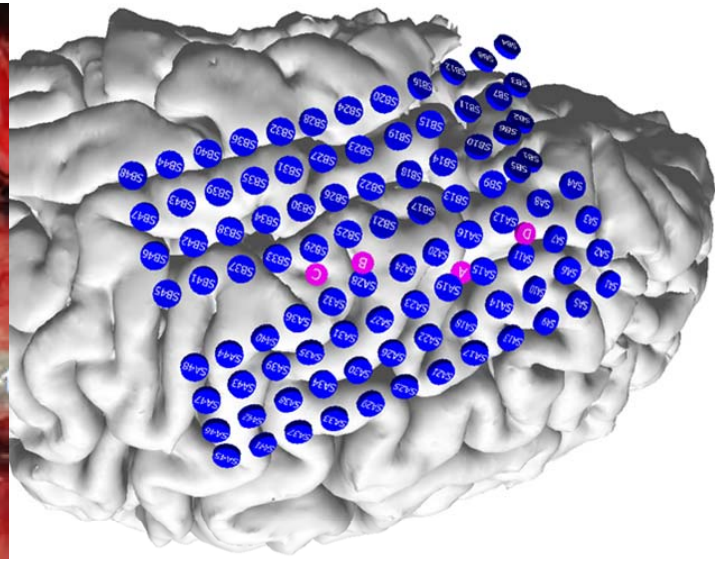
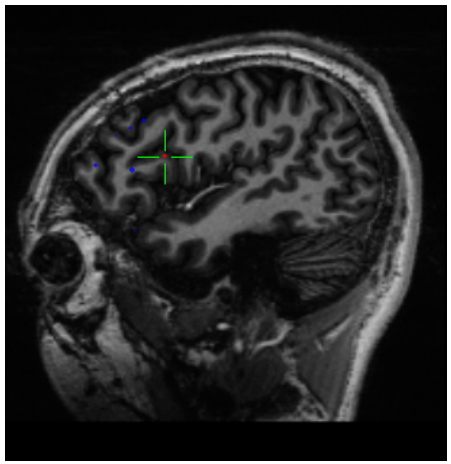
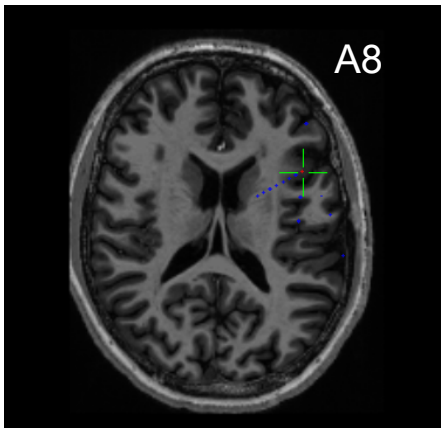
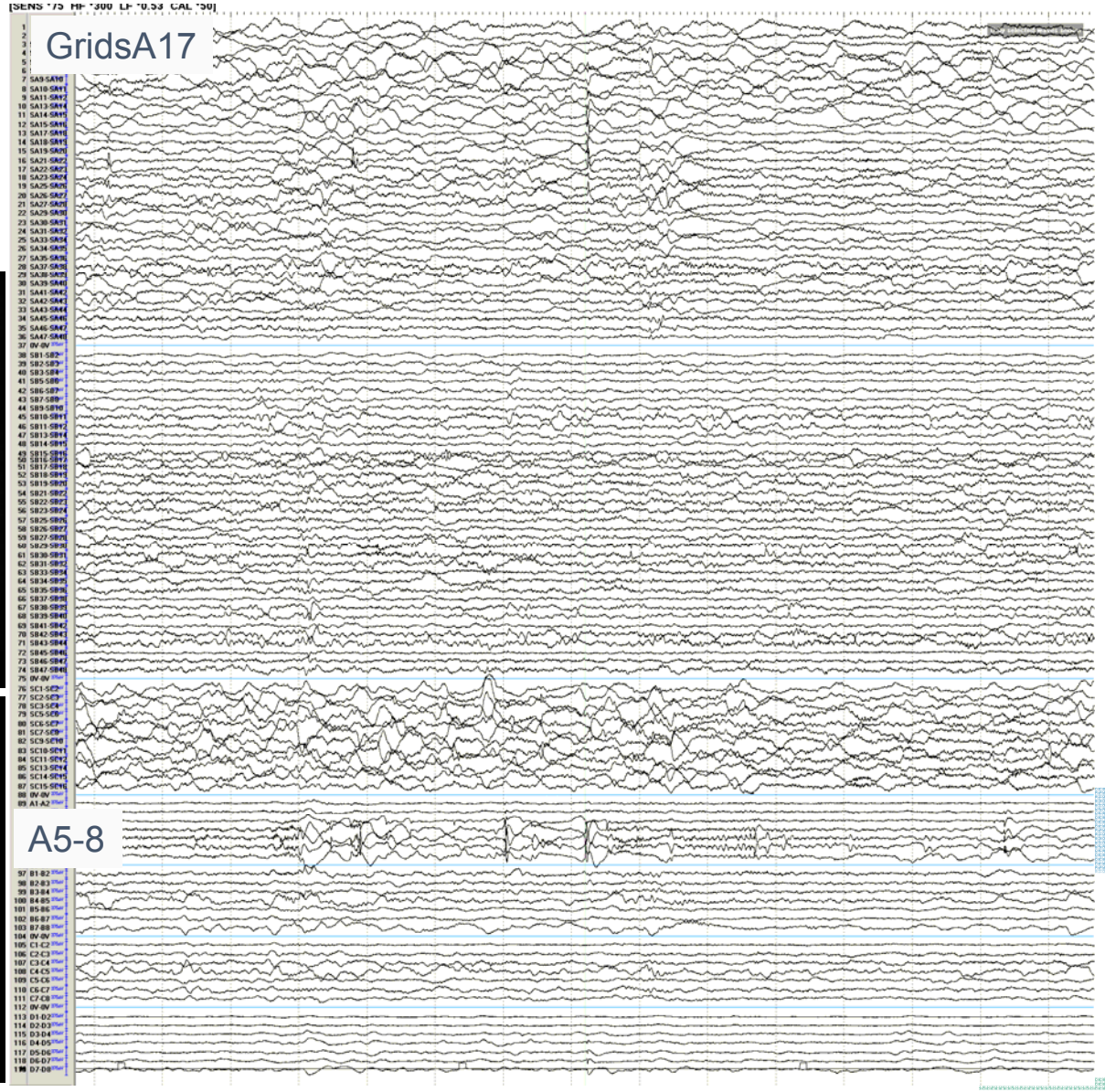
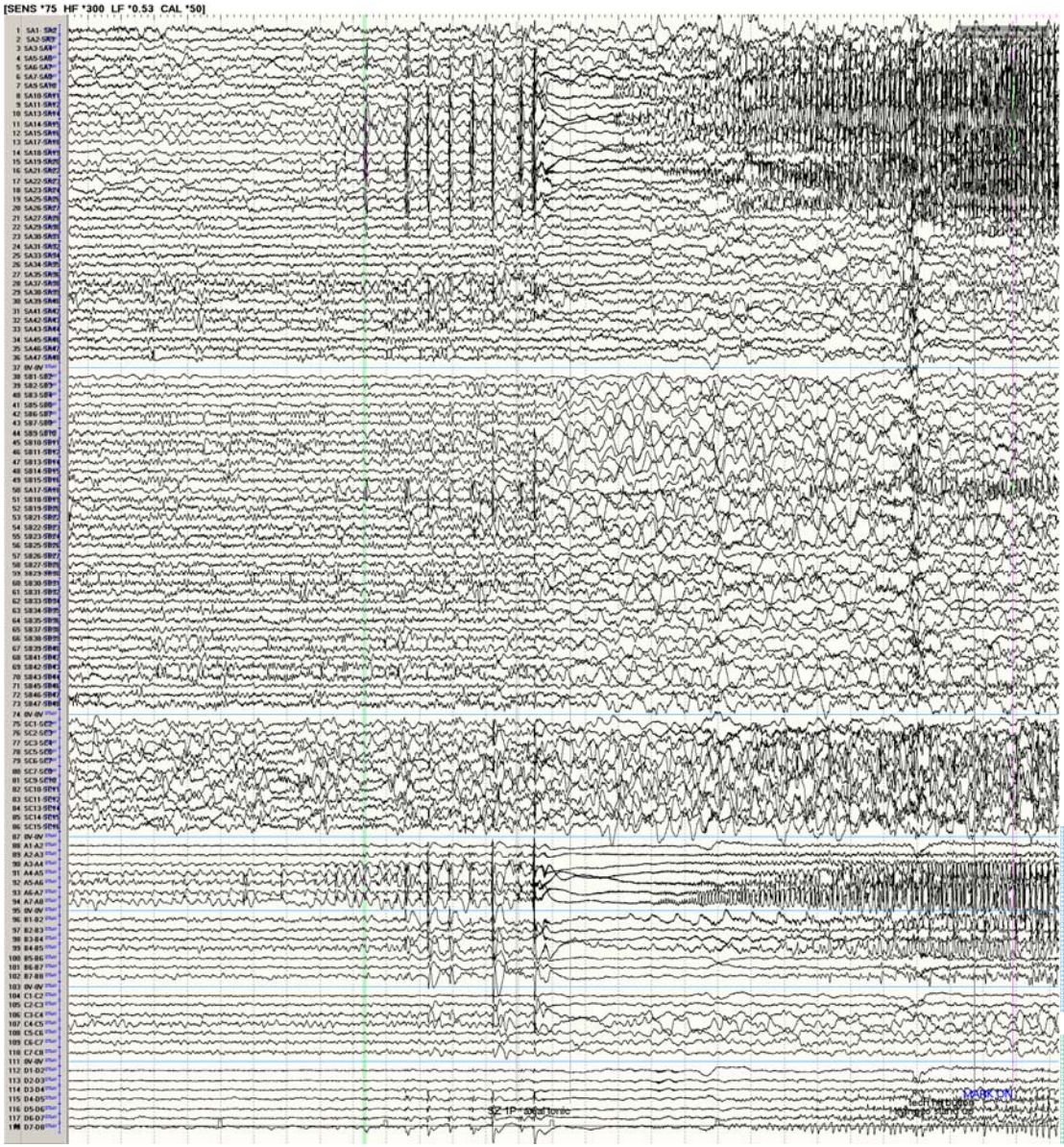







A8


GridsA17
A5-8


[SENS *75 HF *300 LF *0.53 CAL *50]
SZ-1P - axial tonic

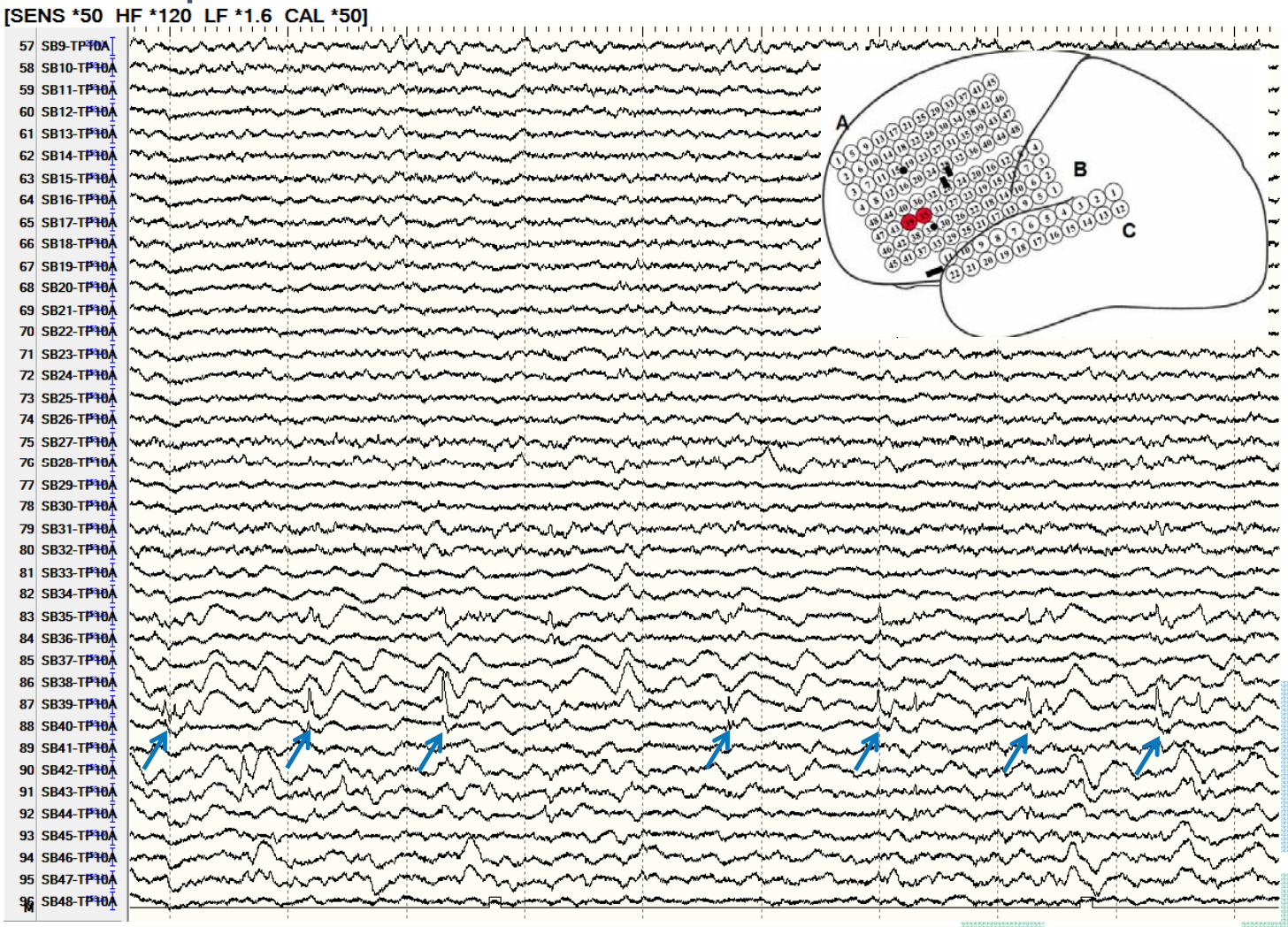
Types of Subdural Interictal Discharges

- Isolated spikes
  - Amplitude >200 μV, frequency >7 Hz, irregular firing
- Repetitive spikes
  - Burst duration > 0.5s, amplitude >200 μV, frequency ± 7-10 Hz, regular firing
- Runs of slow repetitive spikes
  - Burst duration > 0.5s, amplitude >200 μV, frequency < 7-10 Hz, regular firing

Boonyapisit. et al. Epilepsia 2003

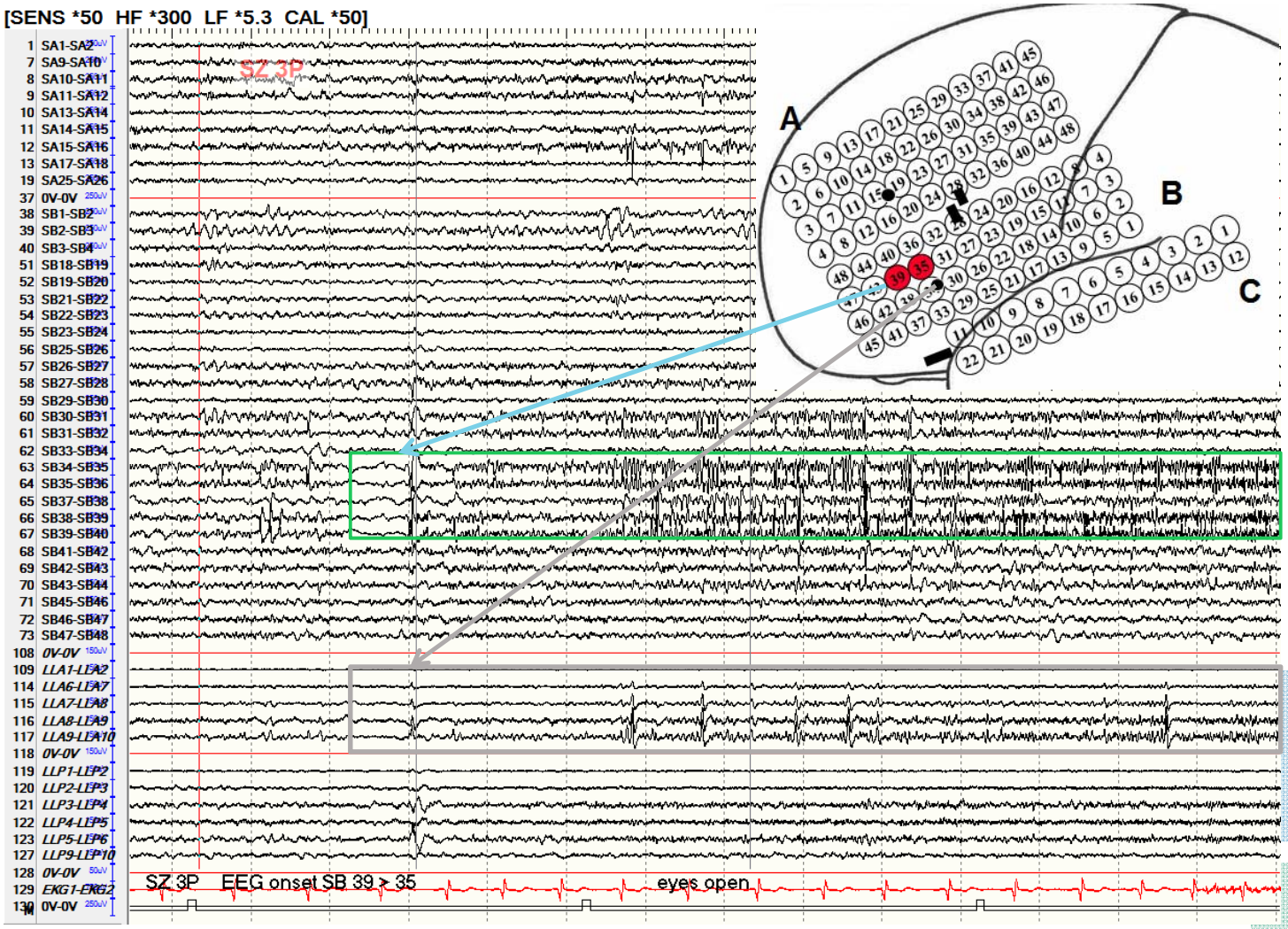
Repetitive Spikes, Left Inferior Frontal

- Paroxysmal Fast and repetitive spikes
  More common in FCD type 2



Chassoux et al. Clin Neurophysiology, 2013
Widdess-Walsh. et al. Neurology, 2007

Ictal onset patterns



Types of Ictal Patterns

Low-voltage fast activity: clearly visible rhythmic activity >13 Hz, usually 5-10 mV in initial amplitude

Low-frequency high-amplitude periodic spikes: high-voltage spiking at 0.5–2 Hz, lasting 4-5 seconds

Sharp activity at <13 Hz: low to medium-voltage sharply-contoured rhythmic activity, most commonly in the alpha-theta range

Spike-and-wave activity: medium- to high-voltage spike-and-wave complexes typically occurring at a frequency of 2–4 Hz

Burst of high-amplitude polyspikes: a single brief burst of repetitive high-voltage spikes

Burst suppression: brief bursts of medium- to high-voltage repetitive spikes alternating with brief periods of voltage attenuation

Delta brush: rhythmic delta waves at 1–2 Hz, with superimposed brief bursts of 20–30 Hz activity overriding each delta wave

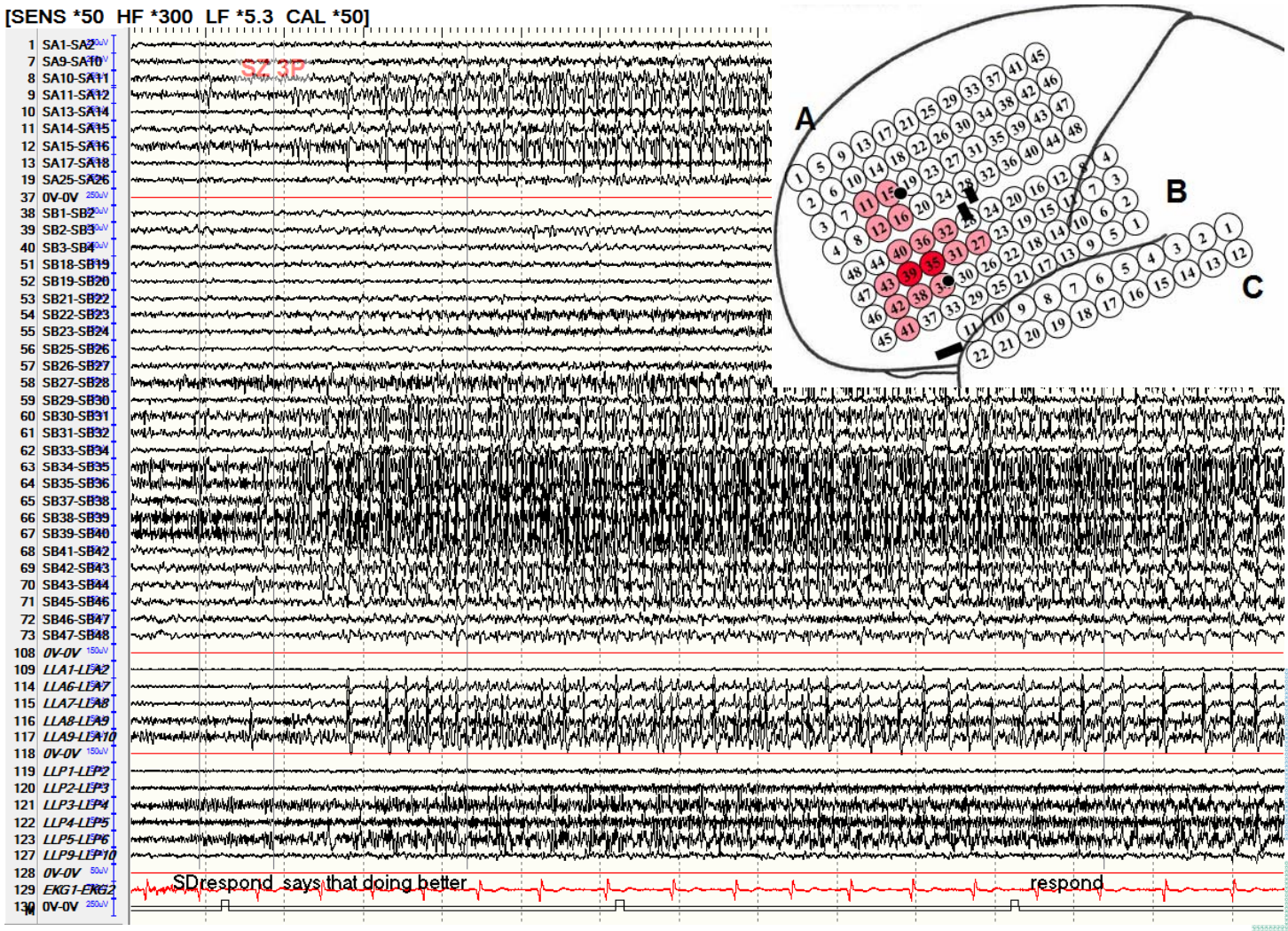
Perucca P et al, Brain 2014:137; 183-196

Subdural and Depth Electrodes

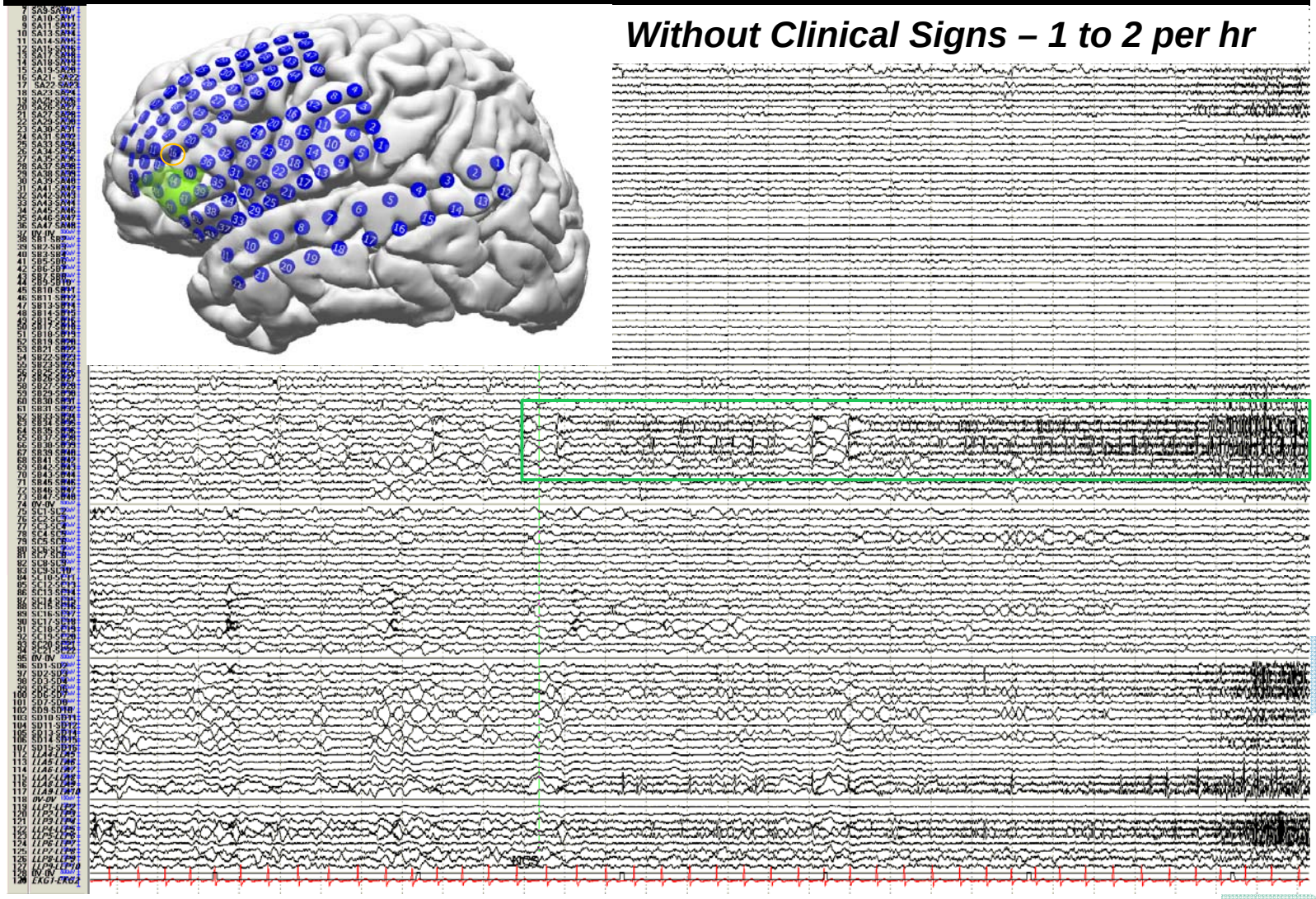
- Advantages
  - Optimal coverage of the subdural space adjacent cortex with adequate and continuous superficial functional mapping capabilities

- Disadvantages
  - Inability to record from deep cortical areas, as in the depth of sulci, interhemispheric regions, mesial temporal or frontal structures, and insula/opercular regions
  - Depth electrodes are not fully stereotactically implanted, their placement may not be very accurate

Vadera S, et al. Neurosurgery. 2013;72(5):723–729


[SENS *50 HF *300 LF *5.3 CAL *50]
SZ 3P
A
B
C
SDrespond says that doing better
respond

Ictal Onset Patterns



Predictors for Seizure Recurrence

- Ictal onset at edge of plate 14%
- Diffuse ictal onset 29%
- > 1 ictal onset zones 35%
- Morphology of ictal onset N/S

Kalamangalam. JCNP et al. 2009

Kim DW. et al. Epilepsia 2010

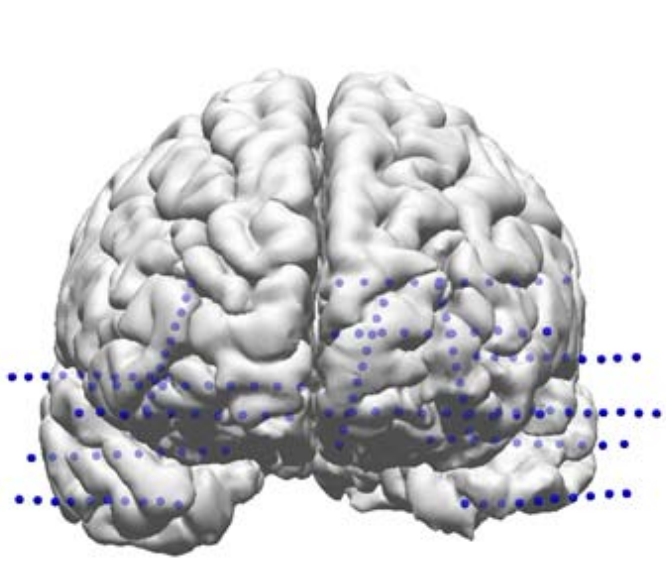
Bulacio JC, et al. Epilepsia 2012

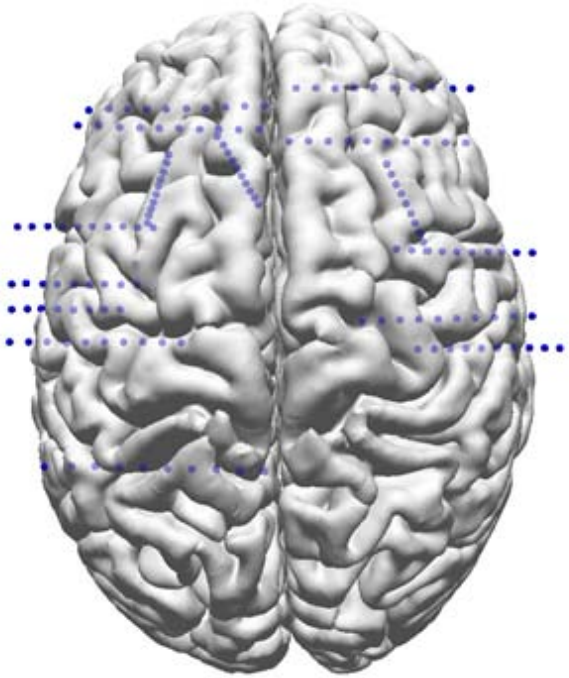
Subdural grids and depths complications

- Most patients who are implanted with SDE tolerate the procedure well
- Meta-analysis(n=2542 patients / 5 deaths)
  - Infections: 1.8 %- 3%
  - Intracranial hemorrhage 4%
  - Acute Focal Neurological deficits 4.6%

Arya R et al, Epilepsia 2013

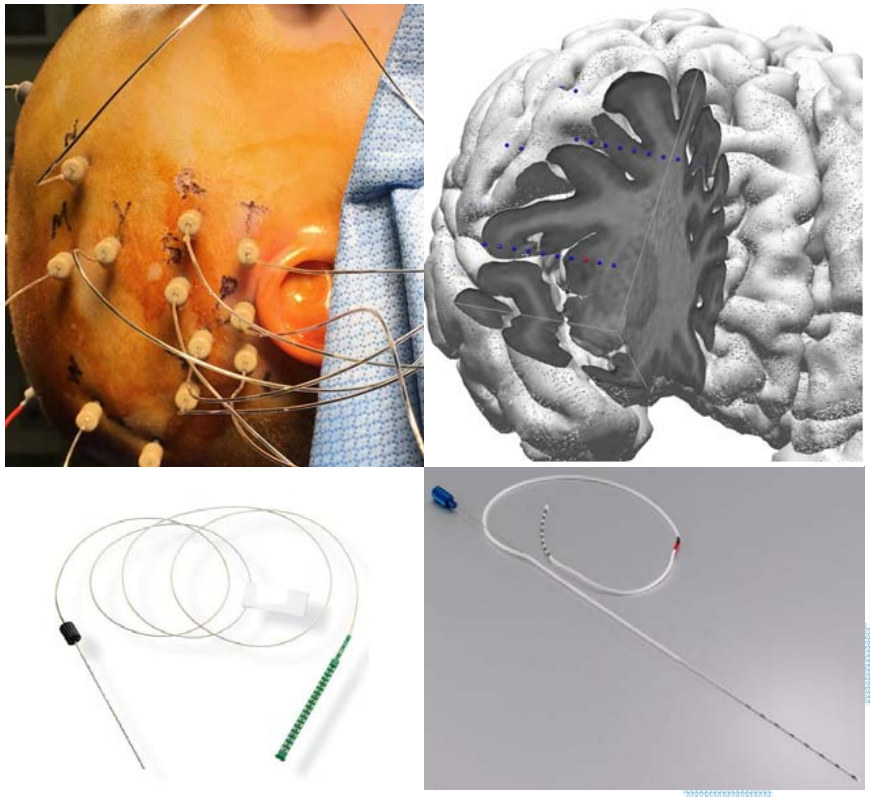
SEEG
“Network”

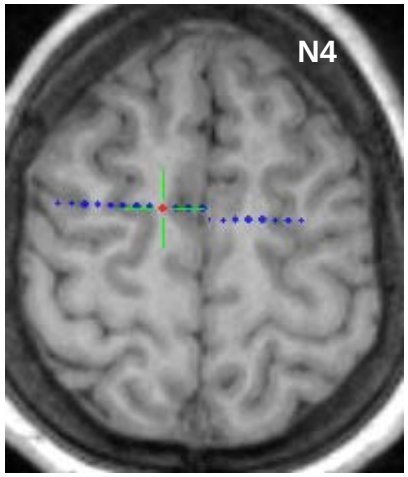


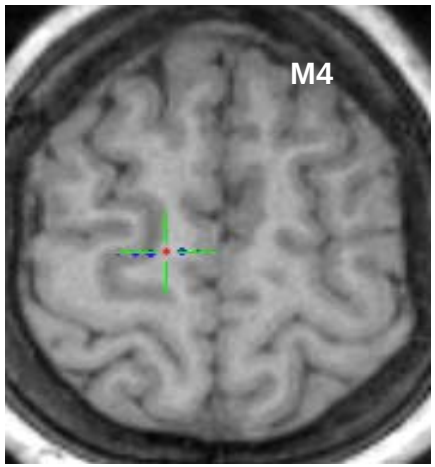


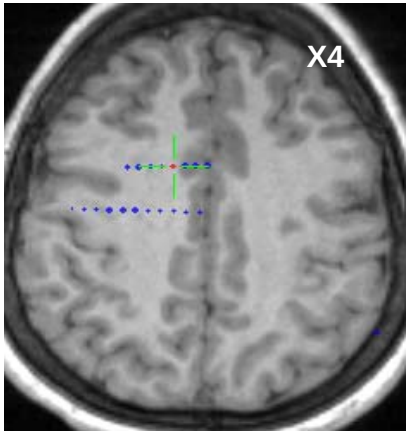
SEEG “Network”

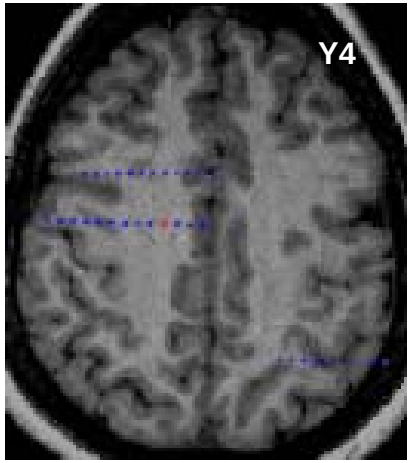
- Presurgical evaluation suggestive of a functional network involvement (e.g., limbic system, parietal-frontal system, parietal-temporal system, etc.) in the setting of normal MRI
- Bi-hemispheric explorations (in particular in focal epilepsies arising from the interhemispheric or deep insular / opercular regions)







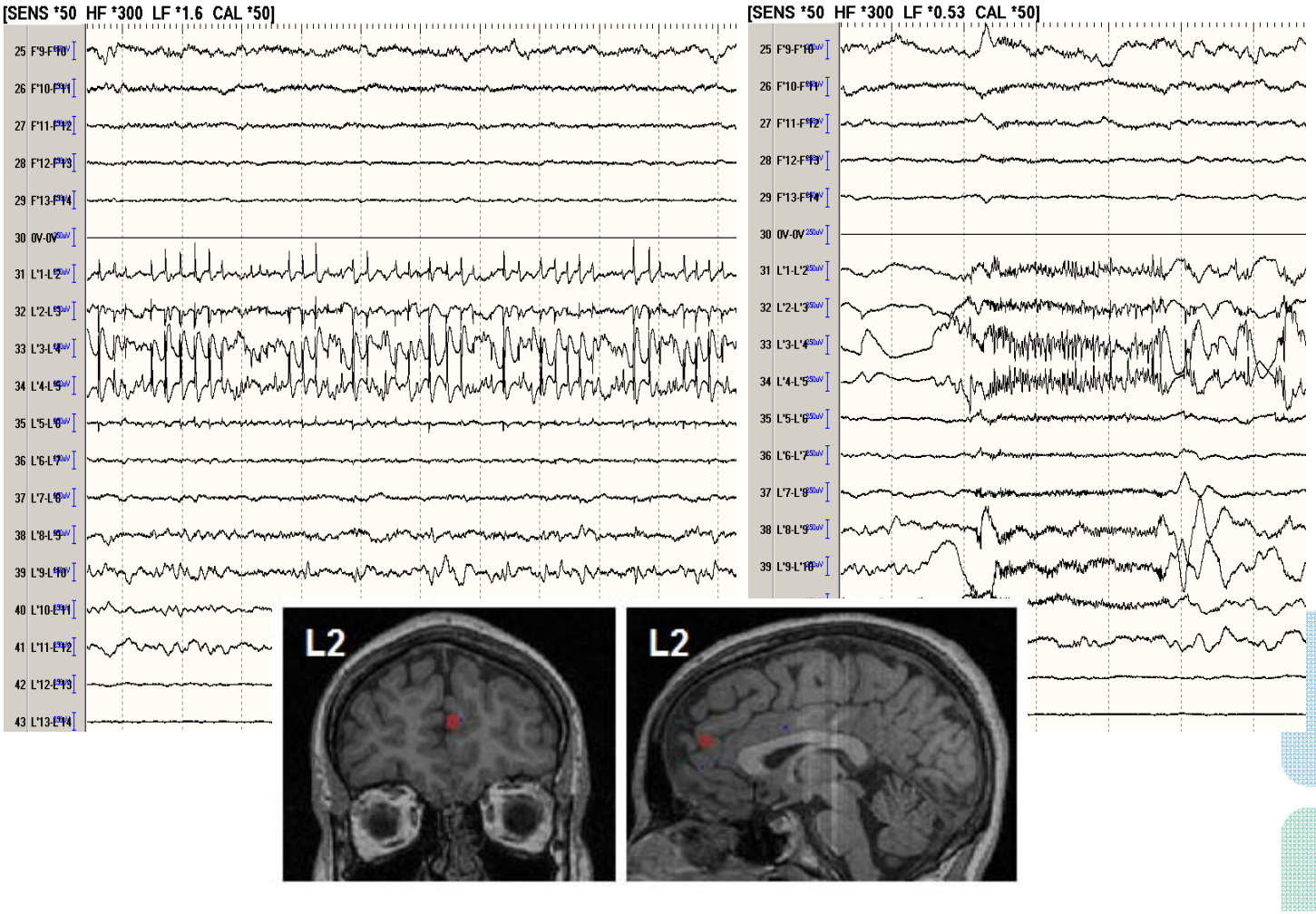




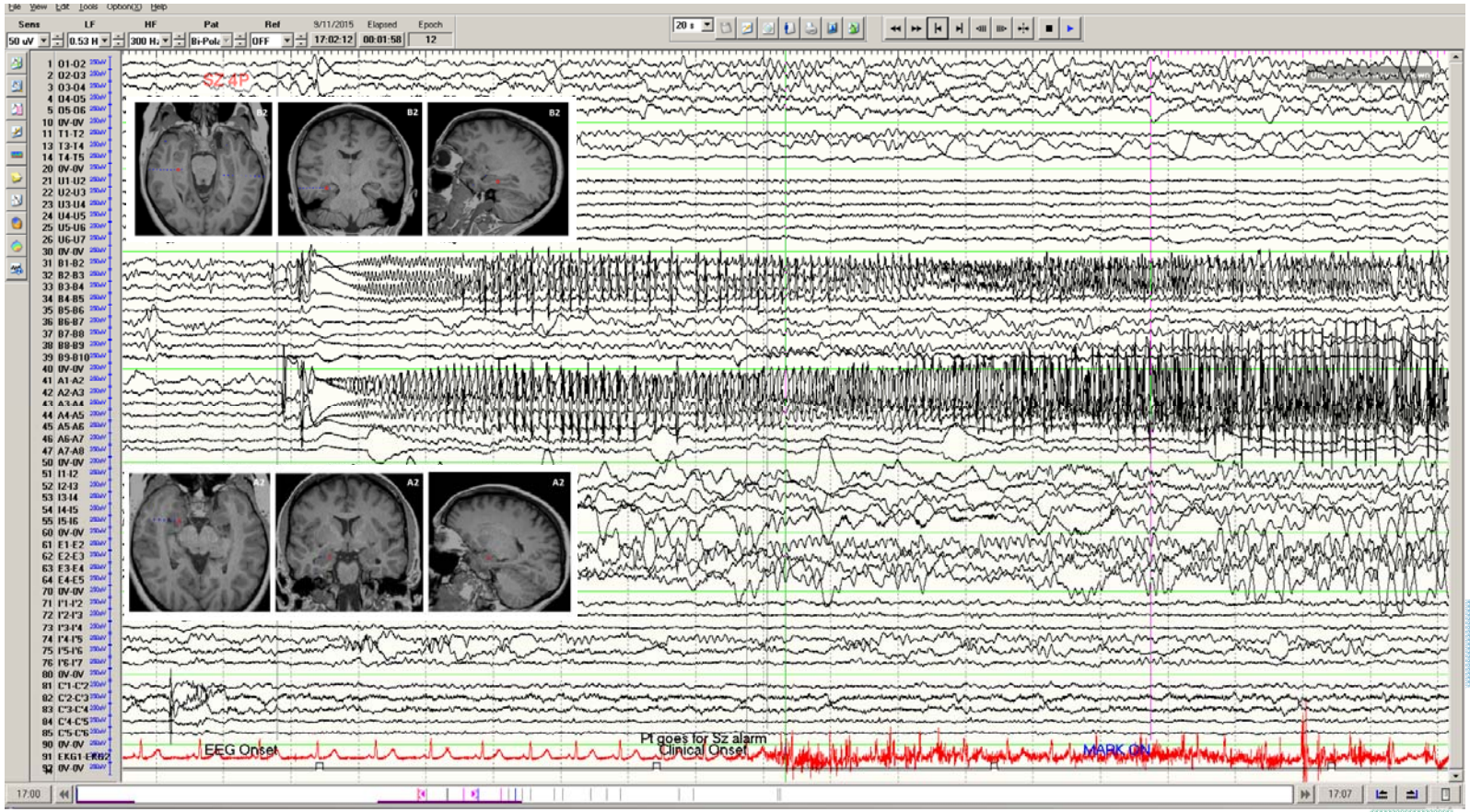
SEEG: Accurate electrode placement

Vakharia VN et al, Epilepsia 2017

SEEG: Interictal Patterns

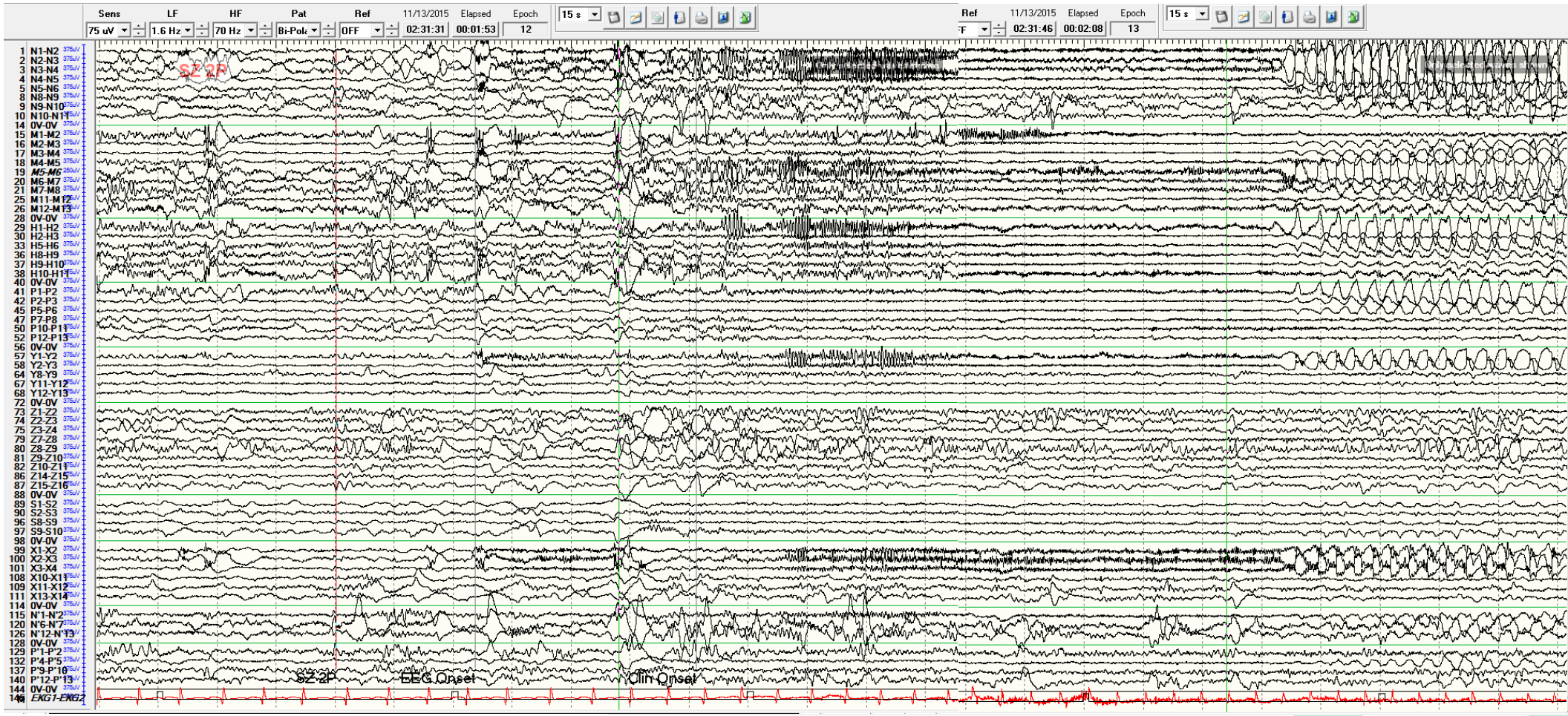


SEEG: Ictal Onset Patterns



Bulacio JC et al; J Clin Neurophysiol. 2016-503-510

SEEG: Ictal Onset Patterns



SEEG
Limitations and Complications

- In neocortical epilepsy and particularly when generator is located over the convexity depth electrodes may suffer from poor sampling
- Disoriented patients may pull on electrodes and cables
- Meta-analysis (n=2624 patients / 5 deaths)
  - The overall complication rate 1.3%
  - Infections: 0.8 %
  - Intracranial hemorrhage 1%

Mullin J. et al, Epilepsia 2016

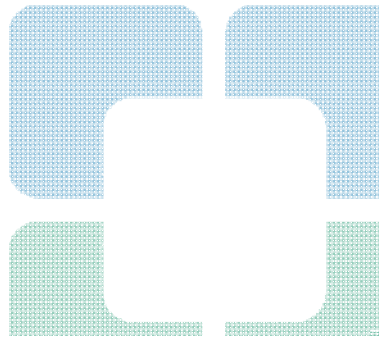
Selection criteria for different methods of Intracranial EEG

Clinical scenario	First option	Second option
▪ Lesional MRI: Potential epileptogenic lesion is superficially located near or in the proximity of eloquent cortex.	SBG	SEEG
▪ Nonlesional MRI: Hypothetical EZ located in the proximity of eloquent cortex.		
▪ Lesional MRI: Potential epileptogenic lesion is located in deep cortical and subcortical areas.	SEEG	SBG with depths
▪ Nonlesional MRI: hypothetical EZ is deeply located or located in noneloquent areas.		
▪ Need for bilateral explorations and/or reoperations	SEEG	SBG with depths
▪ After SDGs failure	SEEG	SBG with depths
▪ When the AEC hypothesis suggest the involvement of a more extensive, multilobar epileptic network	SEEG	SBG with depths
▪ Suspected frontal lobe epilepsy in nonlesional MRI scenario	SEEG	SEEG

Modified from Gonzalez et al, in Wyllie's Treatment of Epilepsy 2015 (Chapter 81).

Remarks

- The areas of the brain where electrodes will be implanted should be selected, based on a very careful analysis of all the data collected during the noninvasive presurgical investigations
- Clear hypothesis and clear questions will lead to a good implantation strategy with the most appropriate techniques
- Only a good implantation will lead to a good surgical outcome

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