Invasive EEG evaluation

Indications and Methods

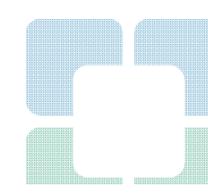
Juan C. Bulacio MD

Epilepsy Center Neurological Institute Cleveland Clinic 2020



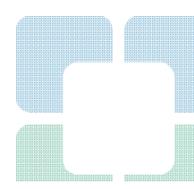
Outline

- 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



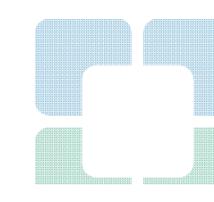
Rationale for the use of invasive evaluation

- 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



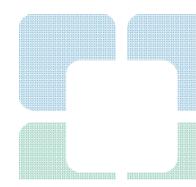


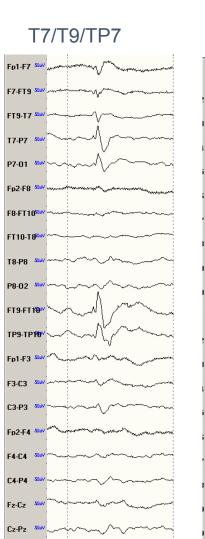
- Adult, right handed
- Aura: mixture of "weird feelings": (fuzzy feeling in her head, strange feeling in the stomach, floating sensation), it will progress to visual hallucinations such as "everything becomes black or blue color".

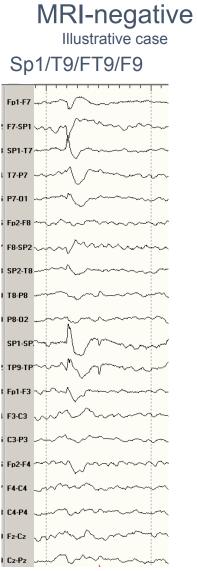
Aura followed by repetitive chewing/swallowing.

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

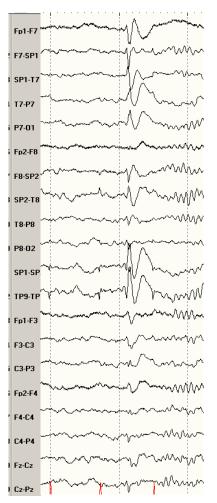
Postictally, can not get words out while knowing what she wanted to say.

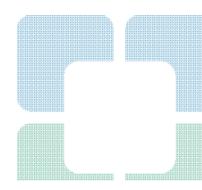






Initial frontal negativity f/by SP1





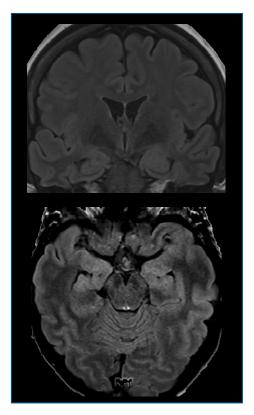
MRI-negative

Illustrative case

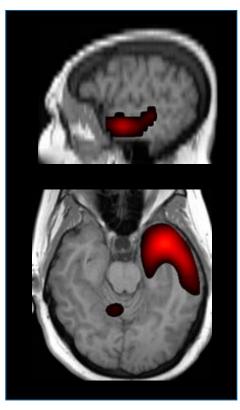
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EEG seizure: Regional bilateral posterior? -> Left frontotemporal Patient complained of visual aura (color)

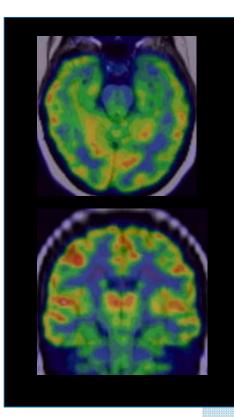
MRI-negative illustrative case



3T MRI: unremarkable

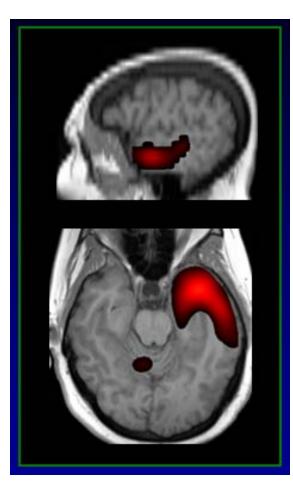


-Left mid superior temporal -Left Posterior basal temporal -Right basal occipital region -Bilateral inferior mesial occipital



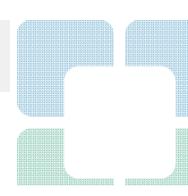
-Left anterior Temporal -Left Posterior Basal Temporal -Left Temporo-Frontal operculum -Lateral Frontal

MRI-negative

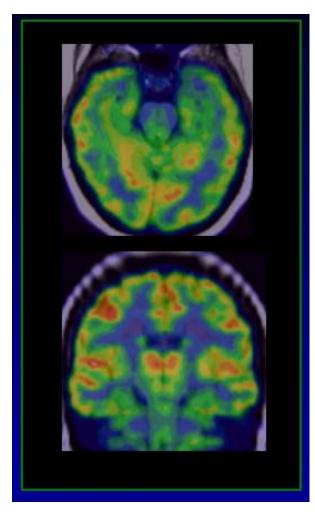


SISCOM has moderate sensitivity in localizing the epileptogenic zone and can provide complimentary information when MRI is negative.

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

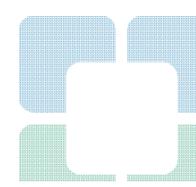


MRI-negative



- 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

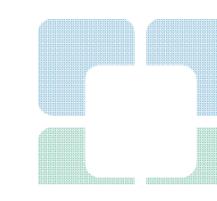


Key points

- 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

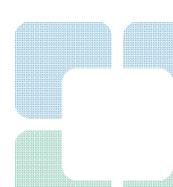
- MRI-negative cases
- Electroclinical and MRI data discordance
- Overlap with eloquent cortex
 - Localize motor, sensory and language function



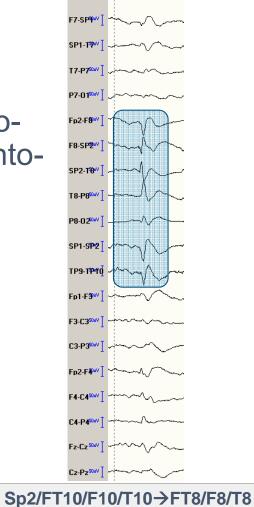
• Seizure history:

- 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

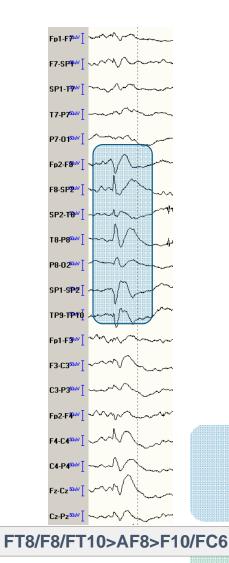
Cleveland Clinic



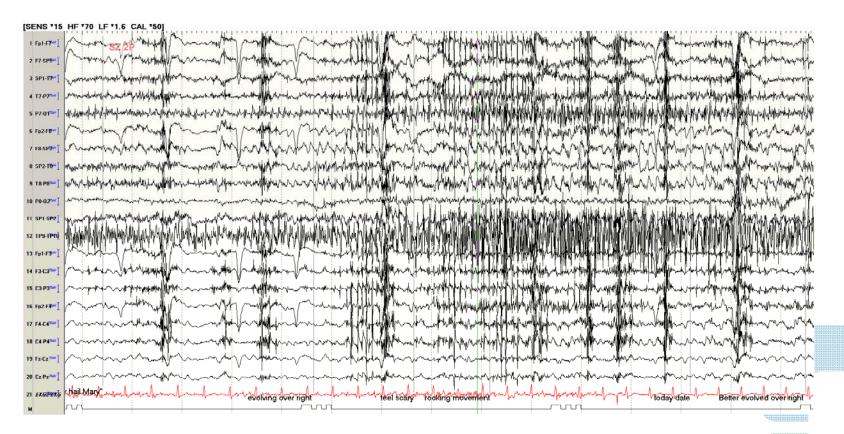
SW right anteromesial and frontotemporal

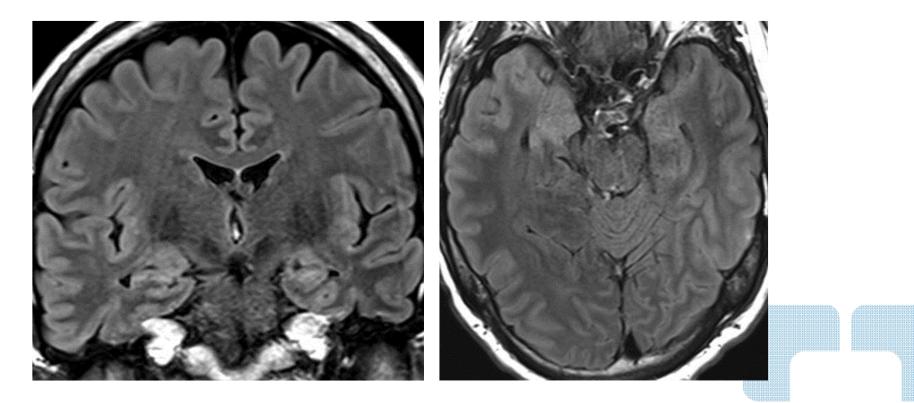


Fp1-F^{90V}

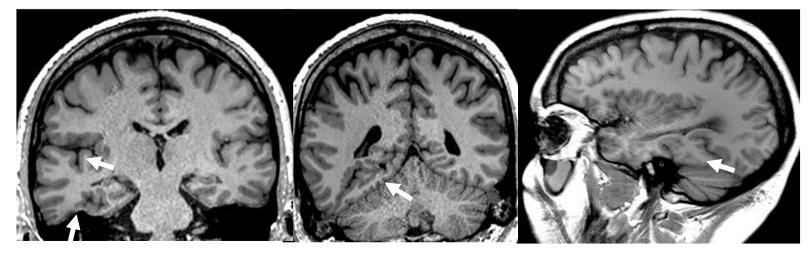


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6 Fp2-F8**	and have been and the second the
7 F8 SP2**	and and the state of the state
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11 SP1-SP2	many providence and the many many providence and the providence of the second of the s
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19 Fz-Cz ***	
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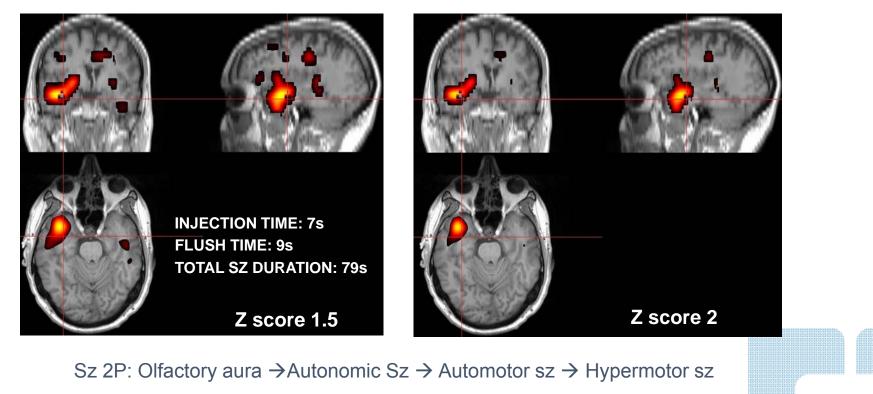


Increased signal in the right hippocampus

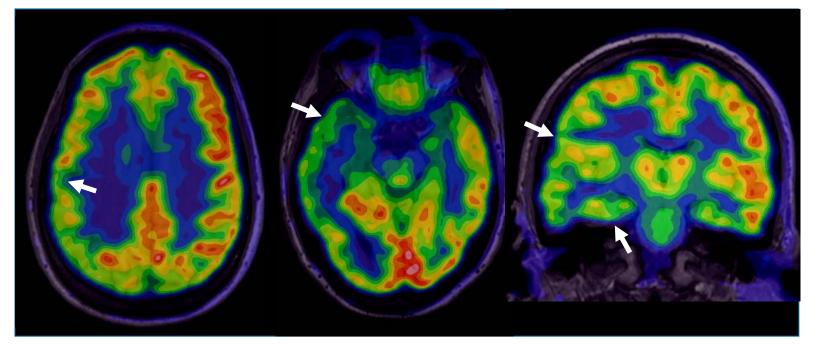


Right hemispheric polymicrogyria with multiple clefts involving:

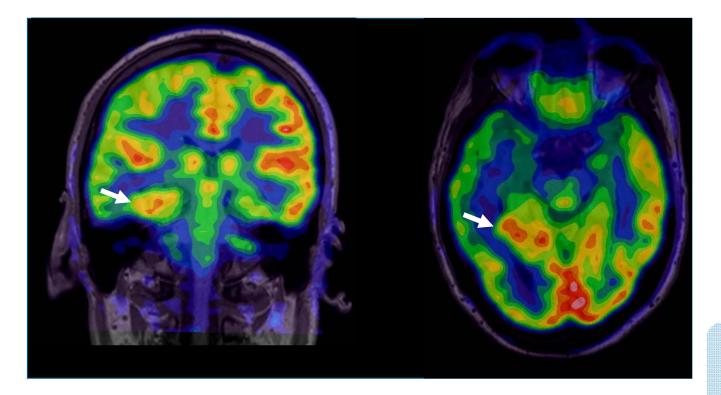
-Right parietal and temporal opercular areas
-Right dorsal insular cortex
-Right temporal/occipital region (with amygdala/hippocampal dysmorphism) and the most of the fusiform gyrus.



Right anterior Temporal region Right Ventral Insular region



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



Hypermetabolism involving the mesial basal temporo-occipital PMG

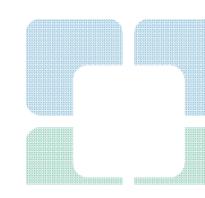


Key Points

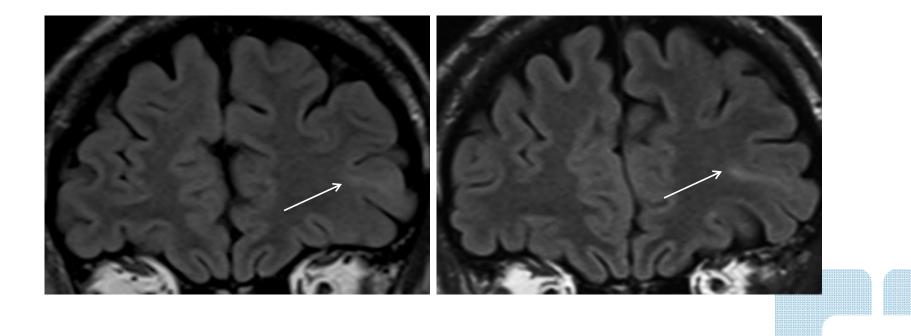
- Two or more anatomical lesions, and the location of at least one is discordant with the electroclinical hypothesis, or both lesions are located within the same functional network and it is unclear if one (or both) of them is (are) epileptic.
- Cases of deeply seated brain lesions (PVNH and BOS FCD).

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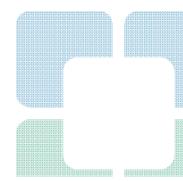


Transmantle Malformation of Cortical Development

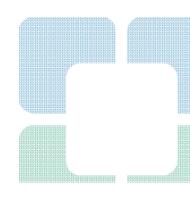


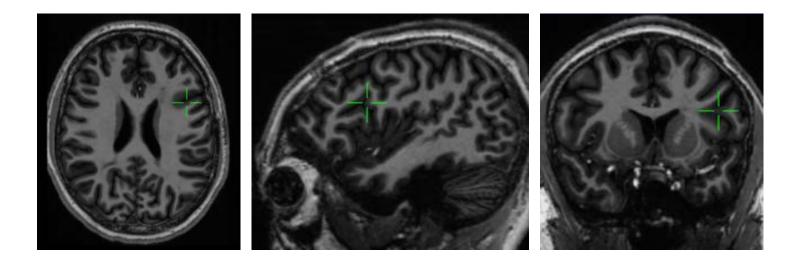
Overlap with eloquent cortex

- 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.



- 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

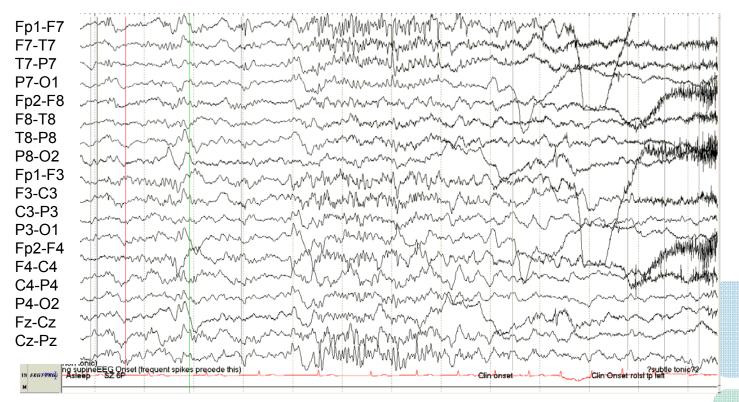


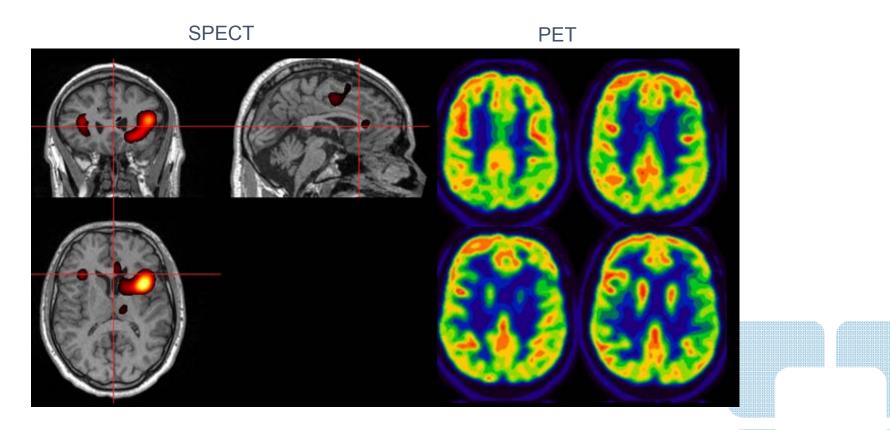


Interictal EEG

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Ictal EEG

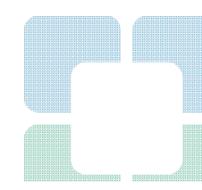




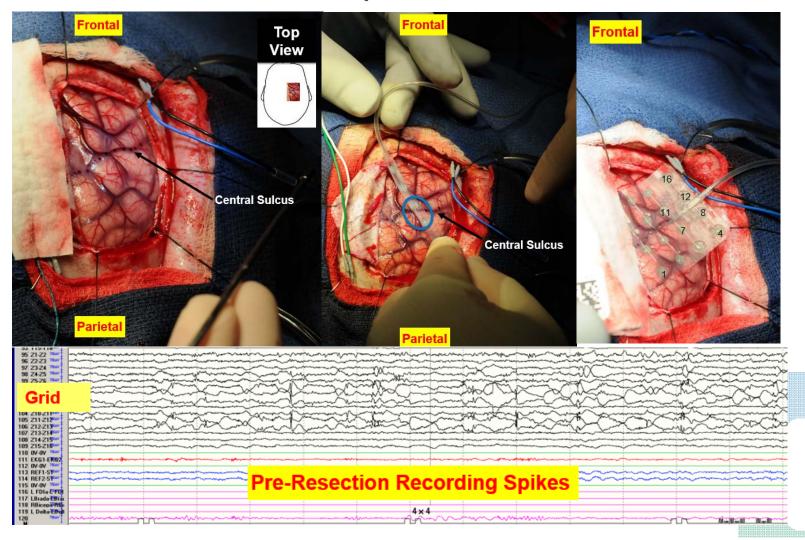
Key points

- 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.

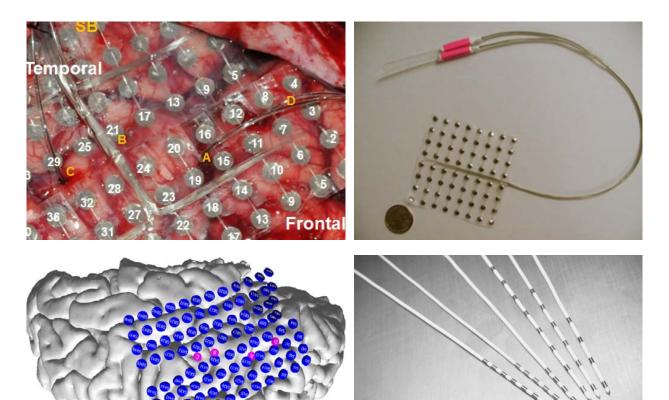
Intracranial Evaluations Methods

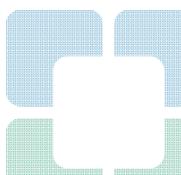


Acute intraoperative ECOG

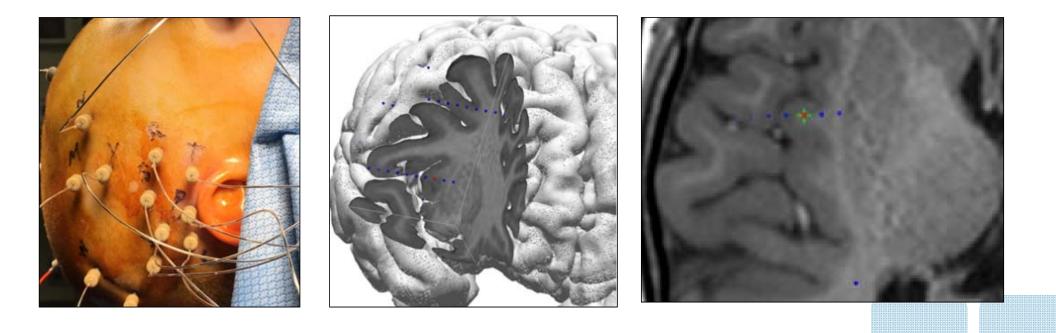


Subdural Grid and Depth electrodes

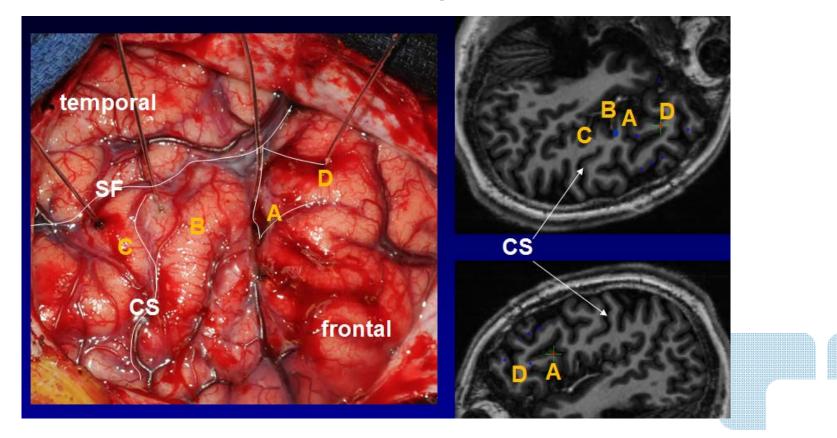




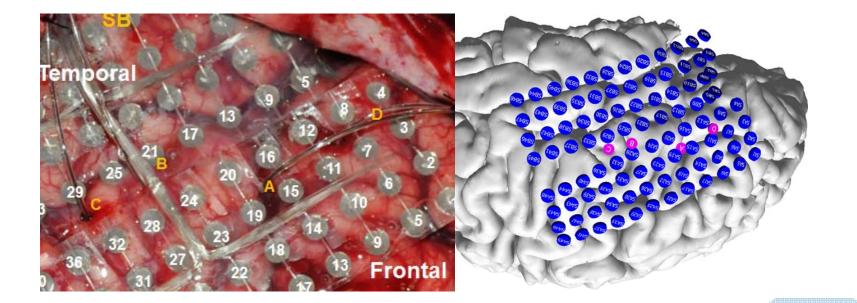
Stereoelectroencephalography -SEEG-

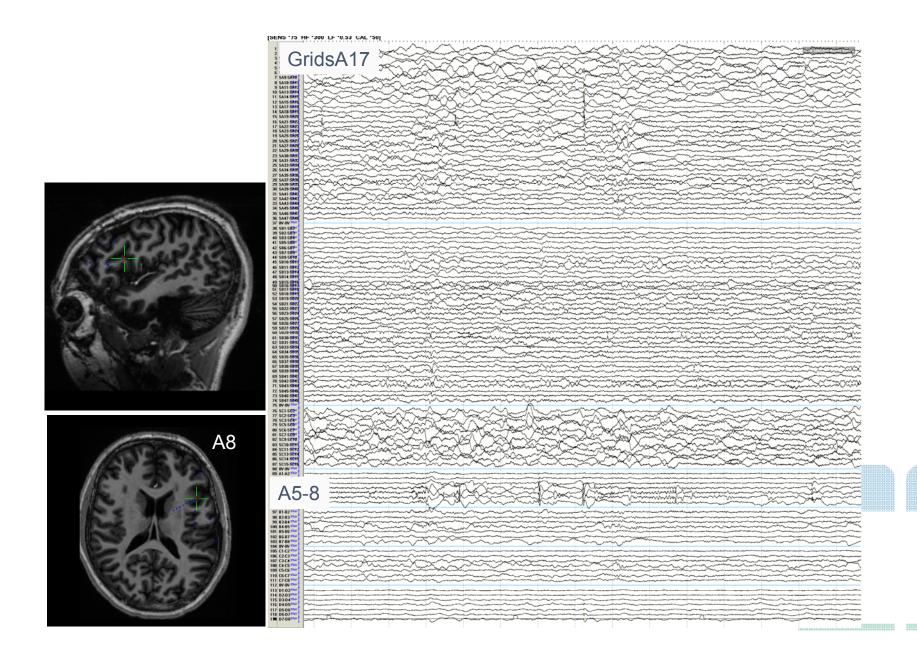


Subdural Grid and Depth electrodes

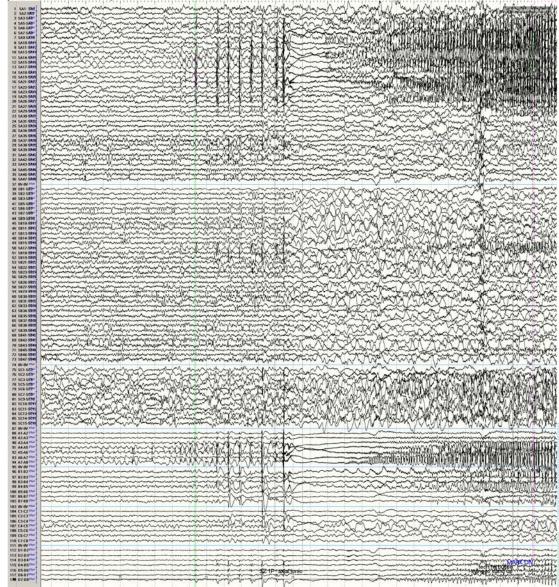


Subdural Grid and Depth electrodes





[SENS '75 HF '300 LF '0.53 CAL '50]



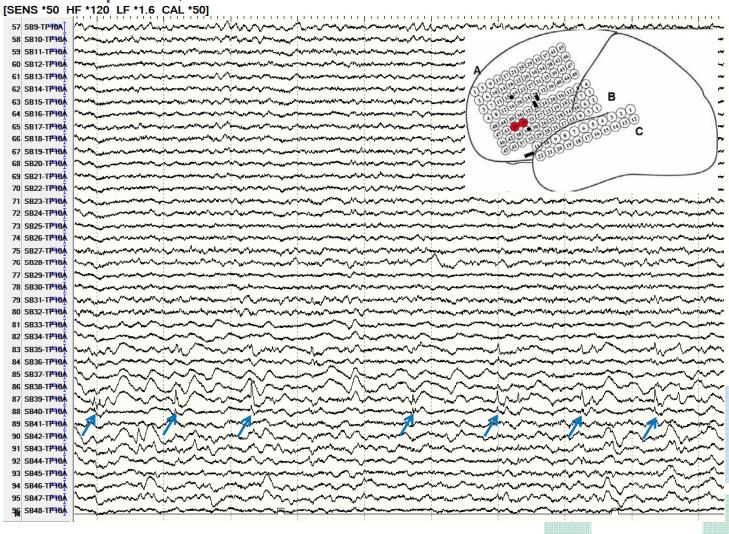
Types of Subdural Interictal Discharges

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

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

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13 SA17-SA18	B communication and the second se	
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57 SB26-SB27		
58 SB27-SB28		
59 SB29-SB30 60 SB30-SB31	1 - margin M Margin Margin Mar	nagene na na na ana ana ana ana ana ana ana
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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

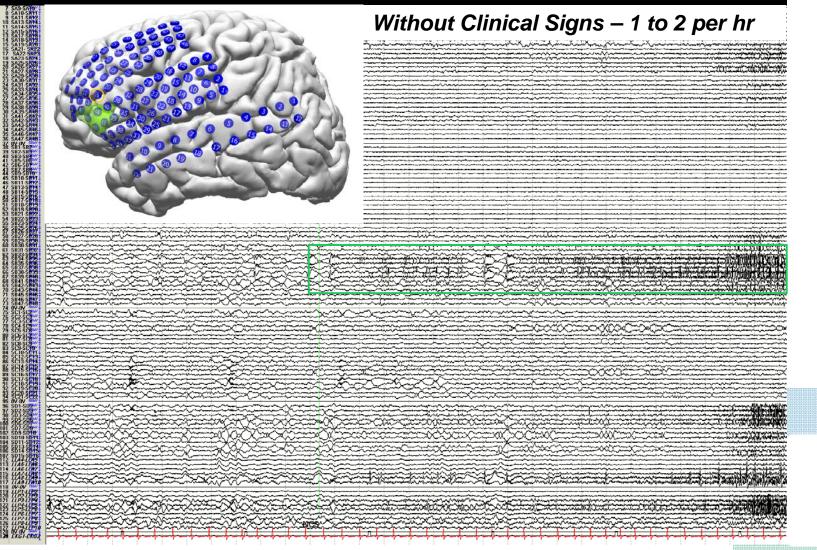
Subdural and Depth Electrodes

- 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

	HF *300 LF *5.3 CAL *50]
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9 SA11-SA12	
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130 0V-0V 2504V	

Ictal Onset Patterns



Predictors for Seizure Recurrence

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

Kalamangalam. JCNP et al. 2009

Kim DW. et al. Epilepsia 2010

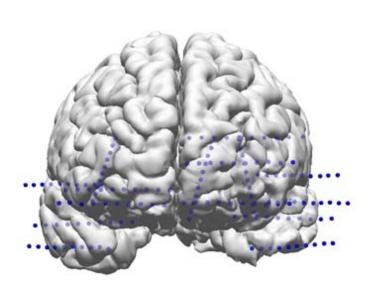
Bulacio JC, et al. Epilepsia 2012

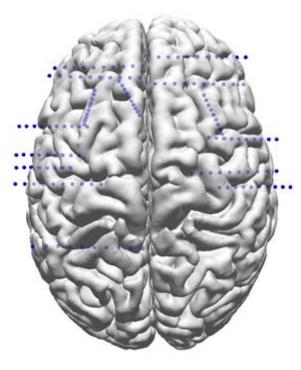
Subdural grids and depths complications

- 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

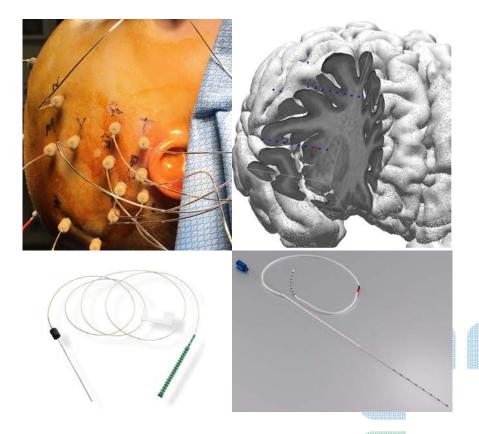
SEEG "Network"

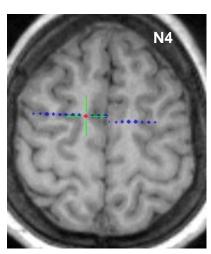


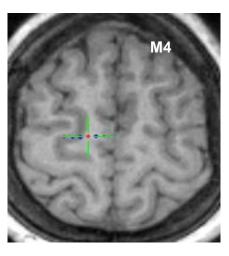


SEEG "Network"

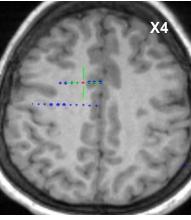
- Presurgical evaluation suggestive of a functional network involvement (e.g., limbic system, parietal-frontal system, parietal-temporal system, etc.) in the setting of normal MRI
- Bi-hemispheric explorations (in particular in focal epilepsies arising from the interhemispheric or deep insular / opercular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

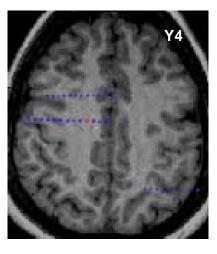






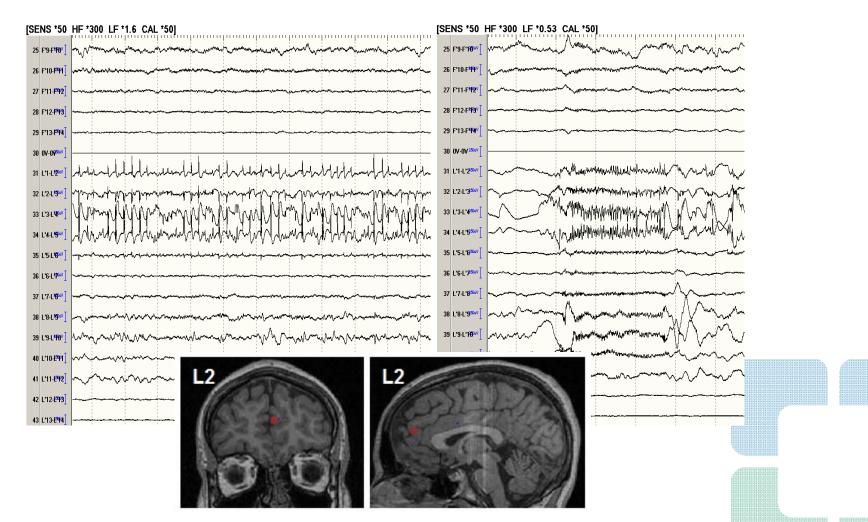
SEEG: Accurate electrode placement



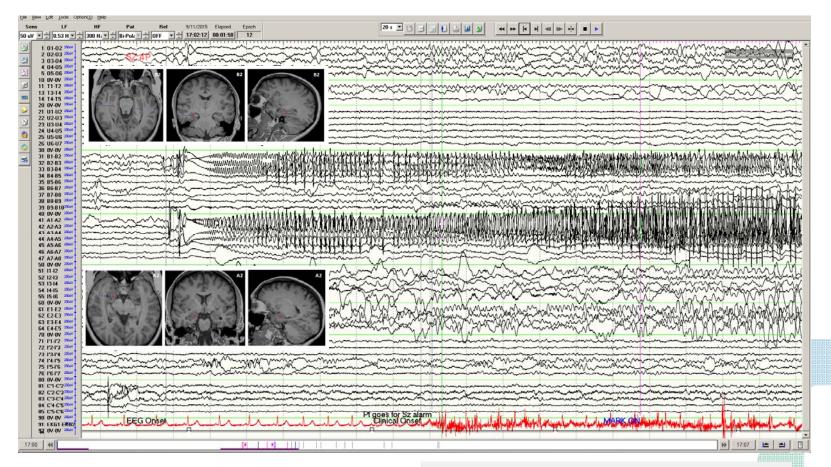


Vakharia VN et al, Epilepsia 2017

SEEG: Interictal Patterns



SEEG: Ictal Onset Patterns



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

SEEG: Ictal Onset Patterns

	Sens LF HF Pat 75 uV - 1.6 Hz - 70 Hz - Bi-Pole -	Ref 11/13/2015 Elapsed Epoch □ DFF ↓ 02:31:31 00:01:53 12		Ref 11/13/2015 Elapsed Epoch 'F -; 02:31:46 00:02:08 13	2
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5 N5-N6 3750/ 8 N8-N9 3750/ 9 N9-N10 ^{3750/} 10 N10-N19 ^{50/} 14 0V-0V 3750/					A THE ALL AND
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37 H9-H10 ^{375.0} 38 H10-H19 ^{50.0} 40 0V-0V ^{375.0} 41 P1-P2 ^{375.0} 42 P2-P3 ^{375.0}	hard hard hard hard hard hard hard hard				
42 F2-F3 45 P5-P6 3750/ 47 P7-P8 3750/ 50 P10-P14750/ 52 P12-P13750/ 56 0V-0V 3750/					MARAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
50 04-04 57 Y1-Y2 3750 58 Y2-Y3 3750 64 Y8-Y9 3750 67 Y11-Y1250 68 Y12-Y1350	harren harr				<u> </u>
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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%

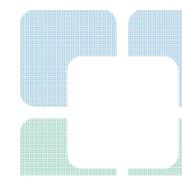
Mullin J. et al, Epilepsia 2016

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. Nonlesional MRI: Hypothetical EZ located in the proximity of eloquent cortex. 	SBG	SEEG		
 Lesional MRI: Potential epileptogenic lesion is located in deep cortical and subcortical areas. Nonlesional MRI: hypothetical EZ is deeply located or located in noneloquent areas. 	SEEG	SBG with depths		
 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





Every life deserves world class care.