Scalp EEG Findings in Temporal Lobe Epilepsy

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Learning Objectives

• Temporal Lobe Epilepsy, a brief review
• Scalp EEG, a brief review
• EEG aspects of TLE with relevance to surgery
Disclosure statement

• Dr. Mirsattari has nothing to disclose
Temporal lobe epilepsy (TLE)

- The most common form of focal epilepsy worldwide.

- Anterior Temporal Lobectomy (ATL) for medically refractory TLE secondary to mesial temporal sclerosis (MTS) is the most commonly performed surgical procedure in the comprehensive epilepsy management centres.

- Surgery is ideally directed towards complete seizure freedom without or with very minimal cognitive or functional deficits.

- A randomised control study demonstrated the effectiveness of surgery in adult patients with medically refractory TLE (Wiebe et al., NEJM 2001;345:311-8.)
International 10-20 system of electrode placements

EEG montages

Bipolar

Common Average Reference Point = CAR

Coronal

Referential
EEG scalp recording: normal, awake
Scalp EEG in TLE

• Electrophysiological assessment remains the cornerstone for assessment of patients with TLE.

• Standard EEG recording techniques with 10-20 system provides limited coverage of the temporal regions.
Scalp EEG for TLE

• Additional Silverman’s electrodes (T1 and T2)

• Anterior one third and posterior two third of a line connecting the outer canthus of the eye and the tragus) are often used in addition to standard 10-20 system to record from the anterior-basal areas of temporal lobes

Additional electrodes to 10-20 system of electrode placement

- May be placed between any of the principal standard positions
Additional Localizing Electrodes

- Mandibular Notch
- Sphenoidal
- Nasopharyngeal
EEG Electrodes for TLE


Interictal EEG Abnormalities in TLE

- Focal arrhythmic slowing
  - theta or delta activity
Focal Slowing in the L T Region
Interictal EEG Abnormalities in TLE

- Focal interictal epileptiform discharges (IEDS) with after coming slow waves in the temporal regions that are often restricted to the anterior temporal areas.
Interictal EEG in wakefulness (27 yrs old)
Interictal EEG in wakefulness (27 yrs old)
Interictal EEG in sleep (27 yrs old)
Interictal EEG in sleep (27 yrs old)
R MTS in MRI (27 yrs old)
Interictal EEG Abnormalities in TLE (#2)

Typical EEG in a R mTLE showing R T slowing as theta-delta activity over the R T regions and R T spikes (*) phase reversing across F8 and T4 electrodes.
Interictal EEG Abnormalities in TLE (#2)

Typical EEG in a R mTLE showing R T slowing as theta-delta activity over the R T regions and R T spikes (*) phase reversing across F8 and T4 electrodes.
Interictal EEG Abnormalities in TLE

- Focal slowing and spikes correlate very well with ictal onset zone:
  - Focal delta (82%)
  - Spikes (90%)

Interictal EEG Abnormalities in TLE

• Focal slowing and spikes correlated very well with the structural abnormalities detected by the MRI in majority of the patients with TLE.

MRI in a patient with R mTLE:
Hippocampal volume loss & signal changes (short arrows)
Poor gray white differentiation in R M T gyrus (long arrow)
Routine Outpatient EEGs in TLE

- Strong correlations for spikes and delta may obviate the need for mandatory ictal recordings in highly well selected patients undergoing presurgical workup with unilateral hippocampal atrophy on MRI and congruent clinical and neuropsychological data.

Ictal EEGs in TLE

• Ictal recordings are usually essential as some patients can have concurrent non-epileptic attacks such as psychogenic non-epileptic seizures (PNESs).

• Bilateral TLE or coexisting extratemporal epilepsy may not be appreciated in routine outpatient scalp EEGs.
Mesial TLE (mTLE) vs Neocortical TLE (nTLE)

- IEDs and clinical semiology aid to differentiate between mTLE and nTLE.

- The interictal discharges remain lateralized to the temporal regions in both.

- In mTLE, IEDs are dominant over the anterior mesial temporal areas (T1/2, A1/2, F7/8, T3/4).

- In nTLE, IEDs are dominant over the lateral and posterior temporal areas (T5/6).

mTLE vs nTLE

• Mesial temporal IEDs occur infrequently in nTLE but neocortical spikes is unlikely with mTLE.
• IEDs in MTS tend to be more localized to anterior temporal region but with increased tendency for bilateral expression than mTLE secondary to tumors.
• Typical anterior temporal spikes can be seen in association with extratemporal epilepsy (e.g. mesial occipital lobe epilepsy which can mimic TLE).

Unilateral TLE

- A portion of patients with unilateral TLE with other evaluation parameters show bitemporal IEDS.

- Most of these patients do well with epilepsy surgery.

- However, increasing bilateral epileptiform discharges are associated with less optimal surgical outcomes.


Prognostic Value of the Spike Dipoles in TLE

• Ebersole Type I spikes: A relatively localized negativity at the anterior temporal electrodes or sphenoidal electrodes with widespread vertex positivity.

• Localizes the abnormality to mesio-basal temporal lobe.

• Associated with a very good surgical outcome.

Prognostic Value of the Spike Dipoles in TLE

• Ebersole Type II spikes: IEDs with relatively localised negativity over the temporal regions and widespread contralateral hemispheric positivity.

• Indicate either temporal or frontal neocortex originating spikes.

Spike Frequency in TLE

• Frequent IEDs or high spike burden (i.e. 60 spikes/hour in one study) is associated with poor outcome after temporal lobectomy (TLY).

• Supportive of the mouse model hypothesis: IEDs are involved with inhibitory physiology controlling seizures (?)

TLE with Oligospikes

- TLE patients with infrequent or absent IEDs
  - IEDs < 1 in an hr on several scalp EEGs
- Have a good ictal localization and excellent surgical outcome similar to patients with frequent IEDs.
- Associated with later onset TLE, less frequent seizures, less SE, less MTS.
- Represents milder degree of MTS without differences in etiological factors.
- Absence of IEDs could suggest extratemporal seizures and would require extra care.

Ictal Rhythms in TLE

• Can be variable even within the same patient.
• In about 90% of patients with unilateral TLE (MRI and IEDs), the lateralization of the ictal changes corresponds.
• Lateralization can be observed at onset in only one third of these patients with unilateral TLE.
• Ictal EEG does not help in differentiating the anterior from posterior lateral TLE.

Ebersole Classification of the Ictal Rhythms in TLE (3 Types)

- Type I: rhythmic 5-9 Hz theta activity that slowly evolves and remains localized to the temporal or sub-temporal regions.
- The most specific pattern for seizures originating from the hippocampal areas.
- Type 1b rhythm: a vertical dipole (mesial basal temporal negativity and vertex positivity) results in a rhythmic parasagittal positive ictal rhythmic activity.
- Type 1C: a combination of Type 1 and 1b.

An example of Ebersole Type I Ictal Rhythm in TLE
Ebersole Type 2 Ictal Rhythms in TLE

- Lower frequency (2-5 Hz) irregular ictal rhythm with widespread temporal distribution.

- Is often associated with neocortical seizures.

An example of Ebersole “Type II” Ictal Rhythm in TLE
Ebersole Type 3 Ictal Rhythms in TLE

• Diffuse ictal EEG changes or attenuation without clear lateralization.

• Is seen both in hippocampal and temporal neocortical seizures.

Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

• Most subclinical electrical seizures confined to hippocampus do not result in surface EEG changes.

Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

• Type I ictal rhythm is observed when the seizures spread from mesial temporal to the infero-lateral temporal structures.

Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

• Type 2 ictal rhythm are often neocortical seizures starting as fast activity (20-40 Hz) on subdural electrodes that are either not detectable on surface EEG or seen as attenuation pattern followed by asynchronous theta-delta activity over the temporal regions.

Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

• Type 3 ictal rhythm occurs when the seizures are confined to the hippocampus, or spread rapidly to the contralateral hippocampus where there is little synchronization of the electrical activity over the inferior lateral temporal structures for expression on the surface EEG.

Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

- Early propagation (< 10 seconds) may suggest more widespread hyperexcitability and greater probability of bilateral temporal epileptogenicity and tends to occur in patients other than pure MTS.

- Best surgical benefits can be expected in those patients with regionalized ictal EEG activity without contralateral spread and ipsilateral interictal changes.
Simultaneous Scalp Ictal Rhythms with Subdural and Depth Recordings

• Switch of lateralization or bitemporal synchrony in the ictal scalp EEG and bitemporal IEDs are probably indices of bitemporal epileptogenicity and are associated with a worse outcome.

• ICA of the ictal onset patterns:
  • seizures with theta rhythm are ipsilateral mesial temporal and basal ganglia onset and then spread to the mesial frontal regions
  • Seizures with delta activity are mesial temporal with spread to the mesial frontal and basal ganglia.

Invasive EEG Recordings

- Are required when noninvasive data are discordant.
- The most important step prior to embarking upon invasive recording is a proper unbiased hypothesis.
- Indications for invasive recording in TLE include either bitemporal epilepsy or temporal plus syndromes.

Invasive EEG Recordings

- Invasive recordings can be performed with multiple subdural lines, subdural grids, depth electrodes or a combination of them.
- There is a high degree of concordance between the subdural and depth recordings in TLE particularly if electrode placement is optimal
  - recording from the surface of parahippocampal gyrus
  - mesial to the collateral sulcus.

Subdurally Recorded Seizures

• In general, most of the subdural seizures arise from the same lobe showing predominant surface IEDs and surface seizures.

• Presence of periodic IEDS prior to the seizure onset in medial temporal lobe structures is often specific for hippocampal onset seizures and correlates well to reduced CA1 cell counts.

Subdurally Recorded Seizures

• The onset in the hippocampal seizures has 13-20 Hz frequencies.
• The onset in temporal neocortical seizures has significantly faster (20-40 Hz) frequencies.
• Mesial temporal sclerosis in comparison to temporal lobe epilepsy not associated with MTS is more likely to have higher seizure onset frequency and is associated with periodic spikes prior to seizure onset.

Two Common Patterns of Temporal Lobe Seizures with Invasive EEGs

- Hypersynchronous rhythmic high amplitude activity (HYP)
  - likely to represent more focal onset
  - lesser rate of spread to contralateral mesial temporal structures
  - associated with more marked neuronal loss in the hippocampi
- Low voltage fast activity (LVFA)
  - more regionalized and neocortical in nature
  - involves both hippocampal and extrahippocampal networks
Subdurally Recorded Seizures

- Subdural patterns may be substrate specific and prognostic.
- Seizures with LVFA and rhythmic sinusoidal ictal patterns are associated with better outcomes after surgery.

Subdurally Recorded Seizures

• Following seizure onset and initial recruitment of the surrounding area, the ictal rhythm propagates variably.

• The spread can be to the ipsilateral temporal lobe, contralateral mesial temporal or temporal neocortex.

• Long interhemispheric propagation times are associated with good surgical outcomes in MTS.

• Time to propagation of the seizure to the contralateral hippocampus is lengthened in direct proportion to Cornu Ammonis (CA) subfield 4 (CA4, a.k.a. the hilar region of the dentate gyrus) cell loss, suggesting a role for CA4 in this process.
“Wasted Hippocampal Syndrome”

- Relatively rare
- Patients with severe unilateral hippocampal atrophy with contralateral ictal onset of seizures.
- In the majority of these patients, invasive recordings show seizures arising from the atrophic side and have very good seizure outcomes with surgery.
- Interictal epileptiform discharges are more likely to correlate with the lateralization of the seizures in this situation.
- It is debatable if these subset of patients need invasive study. In selected patients, noninvasive tests such as SPECT or PET may aid resective surgery without invasive monitoring.
Case 1

• A 30 YO man with medically refractory CPSs and R MTS
• Interictal EEG: R T interictal slowing and spikes localized to the R T regions.
• Six CPSs were captured during video-EEG recordings with rhythmic (Type 1) EEG changes that evolved but remained localized to the R T regions.
• Postictal: slowing and spikes in the R T region.
• Neuropsychology: mild R T dysfunction.
• Rx: R TLY
• Outcome: Seizure free.
• Histopathology: severe R HS in addition to incidentally detected cortical dysplasia in the R T neocortex.
MRI in a patient with R mTLE:
Hippocampal volume loss & signal changes (short arrows)
Poor gray white differentiation in R M T gyrus (long arrow)
Interictal EEG shows right temporal slowing and anterior and mid temporal spikes.
Ictal R T rhythm in one of the CPSs recorded during video-EEG.
Histopathology of the R ATL: marked neuronal loss in CA1, CA3 and CA4 (NeuN stain) with relative preservation of CA2 neurons and subiculum(S).
Temporal neocortex (corresponding to long arrow on MRI) shows focal widening of cortex with blurring of gray white junction (arrows) on NeuN stain. Higher magnification view shows dyslamination and disorientation with accumulation of phosphorylated neurofilament with the dysplastic neurons.
Case 2

- An otherwise healthy and high functioning 60 YO man developed stereotyped CPSs that began at the age of 41 yrs.
- Neurological and neuropsychological examinations: normal.
  MRI: Cavernous hemangioma in the R T neocortex.
- EEG: Infrequent broad IEDs in the R anterior-mid temporal regions in sleep and normal background activity.
- Ictal EEG: High amplitude IEDS in the R anterior-mid T region with ipsilateral hemispheric generalization in 4 seconds. It only minimally spread to the contralateral FP region and lasted 65 seconds without postictal changes.
- Rx: Limited right temporal lobe corticectomy.
- Pathology: Cavernous angioma.
- Outcome: Seizure free for over 10 years on no meds.
Cranial MRI: A. Coronal gradient echo shows susceptibility change (arrow) in R middle T gyrus, abutting on grey matter. B. Axial FLAIR shows the lesion in the R T neocortex.
A typical R T IED involving F8, A2 and T4 during sleep.

Common average referential recording: Sensitivity=10 uV/mm, LFF=0.1 Hz, HFF off
R hemispheric seizure onset in the R T region (F8, A2, T4) with minimal involvement of the R FP2 region.

Common average referential recording: Sensitivity = 10 μV/mm, LFF = 0.1 Hz, HFF off.