Ambulatory EEG in Epilepsy

William O. Tatum IV, DO FAAN, FACNS

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Case

- A 21 year old female without significant past medical history presented to University of Florida student health after experience a GTC seizure.
- She had been out late with her friends partying after studying all night for a chemistry examination.
- Friends described her having nervous tics the morning after.
- Neurological exam and an MRI of the brain were normal.
- Routine scalp awake and drowsy EEG was normal.

She was not treated with ASDs but had a 2\textsuperscript{nd} GTC that led to an MVA…
A subsequent aEEG demonstrated the following…

Reports “small twitch” on activity log
• EDs on EEG predicts recurrence after a first seizure.
• Myoclonic seizures predict long-term treatment in GGE.
• Abnormalities are found in 12–25% of cases for which an inpatient EEG was non-diagnostic, should we use aEEG routinely in cases where long-term treatment is considered?
Yield of IEDs

- More than 1/3rd of patients with epilepsy referred for a CAA-EEG have IEDs.¹
- 0.7% asymptomatic pts had IEDs on AEEG. ¹
- 15.5% and 13.3% with a history or migraine and a +PFHx of epilepsy had IEDs. ¹
- Epilepsy + 1 non-diagnostic EEG (n= 46)²
  - Sleep-deprived increased 2nd study 24%
  - CAA-EEG increased 2nd study 33%.

Latency to First IED

• Diagnosis of epilepsy rests on IEDs.
• In 180 patients undergoing + 96 hr. CAA-EEGs.
  • Latency to first ED= 316 minutes (5.26 hours; R= 70-772 hrs.).
    • < 4 hours= 44%
    • < 8 hours= 58%
    • < 24 hours= 85%
  • 95% of EDs recorded in < 2 days.
• Latency of generalized EDs were sooner than focal IEDs (p= 0.0001) and on awakening are more specific for GGE.²

EEG

• Routine 20 minute scalp EEG is abnormal in 29-55%.
• Sleep deprived EEG increases yield by 24-24%.
• Prolonging the EEG to 60 minutes doubled the yield of a rSc-EEG.
• Repeated rSc-EEG increases yield to 77-90%.
• VEM may be normal in 10-15% of patients.

Ambulatory EEG Monitoring

1970s: 1st systems 4-ch aEEG ¼ inch tape 2 mm/sec for audio-visual review.

1980s: 8-16 channel system with digital time and event markers with cassette tapes and off-head pre-amps.

1990s: advances in microprocessors, multiplexing, real-time, gain/filter adjustments and event recording.

- aEEG becomes high fidelity, web-based, 32-ch, high sampling device with software (SaO2/ECG) and video.¹
- It avoids the “hospital effect” seen with VEM but is limited by the lack of ability to taper ASDs.²
- Cost is 51-65% less than VEM.³

Ambulatory EEG

- AEEG monitoring is a relatively recent technology
- Allows prolonged EEG recording in the home setting.
- Records continuously up to 72 hours increasing the chance of recording an ictal event and EDs during N3 sleep.
- Less expensive alternative to VEM, with costs 51-65% lower than a 24-hour inpatient admission.
- Documented ability to record identifiable focal and generalized epileptiform activity.
Diagnosis & Treatment

- **Diagnosis**
  - Frequent attacks
    - Epileptic
    - Psychogenic
    - Physiologic (sleep, arrhythmia, syncope)
  - Classifying seizure types and epilepsy syndromes
  - Document the Diagnosis(es)
  - The VEM is packed!

- **Treatment**
  - Nocturnal EEG
  - Localization of ED/seizures
  - Quantification of seizures
  - Seizures without awareness
  - Suspected subclinical seizures
  - Validation for Driving
  - D/C after EMU
Sleep-deprive v CAA-EEG after rsEEG?

Multi-center prospective comparison of SD-EEG vs 16-channel CAA-EEG in epilepsy after a non-diagnostic EEG.

• 46 participants had a SD-EEG and CAA-EEG;
  • SD EEG improved detection of EDs by 24%.
  • aEEG improved detection by 33%.
  • aEEG detected seizures in 7/46 (15%) v 0/46 with SD EEG.

Non-Epilepsy and CAA-EEG

- 20-40% have PNEA at referral VEM centers.
- 1 study with 36% of paroxysmal events that was without EEG change.
- Video available to increases yield 35-45%.
- SSMA seizures have 25% that are EEG-.¹
- Artifact pattern may simulate ES but may also help separate them from PNEA.

Choosing and Using CAA-EEG

- Reasons; EEG v VEM vs PSG v Cardiac?
- A baseline EEG should be done initially.
  - Identify BG, focal abnormality & EDs.
  - Identify artifacts (i.e. blink)
- Waist-worn recorder
  - Data analyzed by computer
  - PBA and patient activity log
- EEG stored; intermittent v continuous
  - Seizures-2 minutes prior
  - Spikes- 2 seconds

## Relative Use of EEG in the Evaluation of Paroxysmal Events

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<thead>
<tr>
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<th>Routine Scalp EEG</th>
<th>Short-term EEG</th>
<th>CAA-EEG</th>
<th>In-patient VEM</th>
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<tr>
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Ratings identified with + to +++ from lowest to highest association with the feature. Short-term = < 24 hours.
The Habitual Environment

- Mobility-light pre-amps
  - Typical environment, natural, usual ADL and routines/stresses.
  - 18-32 channels, T1/T2, EKG, EMs
  - 1 pound; 4 AA batteries, 2-4 GB flash memory (2-4 days).
  - Real-time spike/Sz processing
  - Time-synchronized video

- Entire recording, samples & PBA may be chosen to review

- aEEG may be a higher yield than in-patient VEM for some (hospital effect).¹

Modern CAA-EEG Systems

- Most aEEG systems are technologically similar to EMUs.
- Typical aEEG
  - 21+ channels
  - 16-bit resolution
  - 200/256 Hz/channel
  - Polygraphic channels;
    - Oximetry, EKG, EMG
  - USB/Ethernet computer connection for startup, download and review
Yield of CAA-EEG in Epilepsy: PBA

- Retrospective aEEG Results of 344 Outpatients
- PBA of a clinical event in 166/344 (48%)
  - 12% had seizures
  - 36% had non-epileptic events
  - 26% had an additional abnormality
- **Overall clinical usefulness of 74%.**

The Role of aEEG

• Current
  • Document an ictal pattern
  • Distinguish other “events” (e.g. cardiac, sleep, etc.)
  • Classify epilepsy syndrome

• Newer
  • Detect unrecognized seizures
    • Seizures without awareness
    • Non-clinical seizures
    • Nocturnal seizures
  • Quantify subtle seizures
    • Neurologically challenged
    • Witness independence
Choosing in-v out-patient VEM

**Inpatient**
- Need to have medication tapered.
- Pre-surgical evaluation with invasive electrodes.
- Seizure behavior could jeopardize safety during events (supervision).
- Adjunctive testing needed (iSPECT)

**Outpatient**
- Frequent non-disabling events.
- Others can observe/chart events.
- Avoids hospital environment effects.
- Assess EEG integrated between ADLs, home situation, and “events”.
A 67 y/o male complained of dizzy spells. He had a past medical history of hypertension, diabetes, and coronary artery disease with an MI and 3 stents placed after experiencing infrequent “blackouts”. She was seen by his PCP who diagnosed syncope. Cardiology performed a HUT test which was “positive”. He was diagnosed with syncope and treated conservatively after an ILD. Spells of brief dizziness, sweating, nausea pallor and “blacking out” continued. Neurology evaluated her and suspected syncope v seizure. An MRI brain was normal. An aEEG revealed a left temporal seizure.

He was placed on Leviteracetam but became depressed and suicidal. A sleep-deprived EEG at Mayo was normal.
The seizure on an EEG was recovered…
Automated Artifact Removal

- Ideal EEG reflects only cerebral activity (v extracerebral activity)\(^1\).
- CAA-EEG Artifact Elimination
  - Post-hoc algorithms
    - HFF=frequency domain
    - May modify brain activity.
  - Rejection/subtraction
    - ICA = spatial domain
  - Reduction
    - Intended for EMG, eye movement, and electrode.
    - Ineffective for other types.

http://www.accessdata.fda.gov/cdrh_docs/pdf13/k133793.pdf
Filtering in CAA-EEG

Over-filtering

Courtesy Mark Schuerer P12; Persyst 2015®
Case

BJ is a 53 y/o RHWM with OSAS, HTN, hyperlipidemia, chronic anxiety-depression seen on referral from continuity clinic. His main reason for being seen was to address driving. 1 year ago he ran out of Buproprion and 10 days later he developed a “blackout”. Feeling “bad” he went to the ED where a GTC was witnessed. He was loaded with admitted and given OXC. An MRI of the brain suggests left MTS. EEG was normal awake-sleep.

He developed side-effects from OXC and slowly weaned himself off ASDs. He reported no further symptoms of any kind and requested the seizure diagnosis be removed from his medical record and driving restrictions relaxed. He has been 6 months with no events at all. The EMU is “slammed” for 3 months.
On CAA-EEG he had 2 focal seizures without awareness
• About 6-15% of aEEG studies have “subclinical” seizures.
• Seizures without awareness are common.
Seizure Awareness

Seizure self-reports may be unreliable. 1-3

- VEM study (n= 21) 1:
  - 26% always aware of Sz
  - 30% never aware

- CAA-EEG (n= 502; 28.5 hrs.): 2
  - 8.5% had Seizures (n=47)
  - 62% always recognized
  - 23% with no PBA

- Left temporal location predictive. 3

Chronic Intracranial CAA-EEG

- CAA-iEEG safety established for > 5 years.\(^1\)
- More detections on RNS than diary entries\(^1,2\)
- Diagnostic as well as a treatment.
  - B/L seizures identified in 36.2% (25/69) of bitemporal epilepsies; 1\textsuperscript{st} B/L seizure @ 41.6 days BUT most EMU stays <5 days.
  - In 20% the suspected lateralization changed; 64% felt to be U/L were really B/L, and 13% felt to be B/L were U/L

Closed Loop CAA-Intracranial EEG

• Sz are detected on CAA-iEEG with stimulation in response.
• Safety established for CAA-iEEG > 5 years.¹
• A greater number of detections than diary entries¹,²
• Different pathologies produce iEEG patterns.²
• Moderate IIR shown on CAA-iEEG in > 7000 ECoGs.³

¹. Bergey G. Neurology; 84(8):810, 2015
². Palmini A. Epilepsia; 51(Suppl. 1):23, 2010
Emerging CAA-EEG Technology

- In-ear ambulatory EEG with an earpiece that connects to subdermal electrodes embedded under scalp outside skull.
“Based upon video alone, readers correctly identified ES with a 93% sensitivity compared with EEG with a sensitivity of 89%.”
“Even the finest equipment cannot make up for the deficiencies in quality of the technical and professional personnel. Unless carried out with consistently high technical standards and provided with interpretation that are clinical reliable…monitoring…is simply an expensive waste of time.”

THANKYOU
Tatum.william@mayo.edu