EEG Delirium Assessment: Evolving Research & Clinical Roles

Presenters: Eyal Kimchi, MD, PhD and Gen Shinozaki, MD

Time	Section
01:39	**Delirium is a complex mind/brain syndrome** • How to identify delirium? (main methods: DSM-5 and CAM) • Limitations: in routine practice, many cases of delirium go unrecognized • Complex, but not Random (predisposing factors and precipitating factors)
03:55	**Brain-Based Delirium Measurement?** • EEG as a biomarker of delirium and delirium severity • EEG results of someone without and someone with delirium (differences in wave shapes) • Clinical EEG Slowing Correlates with Delirium Severity o Generalized theta or delta slowing was associated with delirium • EEG Slowing reflects delirium more than arousal • EEG Slowing is present in patients with Hypoactive and Hyperactive Delirium
08:08	**EEG Slowing Correlates with Clinical Outcomes** • Patients with EEG slowing tend to stay longer in the hospital and patients with clinical delirium also tend to stay longer in the hospital • Patients with EEG slowing tend to have worse clinical outcomes at discharge and patients with delirium also tend to have worse clinical outcomes • Mortality: in this study cohort, only those who developed EEG slowing died

09:50	**What about EEG features other than slowing?**
	• Routine Clinical EEG Interpretation: looking for any abnormalities in background rhythms
	  o These rhythms are important for states of arousal
	  o Usually look for discharges (Epilepsy)
	• Visual EEG-Based Grading of Delirium Severity
	  o 404 patient cohort receiving EEG for Altered Mental Status
	  o Most visual EEG features are associated with someone's delirium severity (VE-CAM-S)
	  ▪ VE-CAM-S is correlated with mortality in the hospital and up to 3 months

13:35	**What about EEG features that are hard to see?**
	• Machine learning EEG delirium severity prediction
	• List of EEG features that are now computational in nature and not visual
	• E-CAM-S: EEG Confusion Assessment Method Severity Score
	  o Cannot make a clinical diagnosis based on this alone
	• Importance of variability of EEG features over time
	  o Variability of slowing over time, etc. (the visual is showing standard deviations)
	• Spatial Topography of Delirium Pathophysiology?
	  o Front to back brain axis was associated more with a differential rate of delirium than the hemispheres right to left
	  o Can predict delirium severity based on the electrode pairs
	  o Antero-Posterior Topography of Delirium: as the antero-posterior distance between the electrodes grows larger the correlation with delirium severity grows
	  o Matches with quantitative data

19:45	**Organization of Delirium Pathophysiology** • Slowing is the single most informative EEG feature for delirium (biomarker) • Visual or quantitative EEG features beyond slowing may help predict delirium severity • The variability of EEG features over time may help predict delirium severity • Delirium pathophysiology may particularly involve anterior-posterior cortical brain networks
21:14	**Some EEG Advantages & Limitations** • Advantages

	○ Applicable at the bedside ○ Reflects core delirium features ○ Validity across phenotypes (hypoactive & hyperactive) ○ Quantitative data ○ High temporal resolution • Limitations ○ Something is placed on the patient ○ Spatial limitations (samples large brain regions, sample primarily superficial cortex) ○ Limited etiologic information ○ Traditionally requires expertise (placement of EEG, interpretation of EEG)
25:17	**Game-changing approach for delirium: Novel EEG algorithm for detection and outcome prediction**
25:35	**Publications**
25:48	**Question** • Why do we measure blood pressure?—look for at risk people to do something to help them • How about glucose? • Imagination: think of a family member who may be admitted to a hospital
27:05	**The CAM-ICU**
27:29	**Traditional EEG** • Delirium can be detected by a traditional EEG ○ But, not practical for every pt even with high risk ○ Machine is too big ○ Technician needs to place multiple leads ○ Neurology specialist to interpret • EEG findings for delirium ○ EEG findings are "diffuse slowing" = slow wave (delta-theta) across all 20 leads ▪ No need for 20 leads to detect diffuse slowing ▪ Only a few leads are enough ▪ It is proven through systematic evaluation of many EEG pairs • Used in other areas ○ Anesthesiology (monitoring for depth of anesthesia, BIS monitor, Entropy, etc.) ○ ECT machine (monitoring for seizure activities)
29:44	**Delirium EEG Study** • To test if a simplified EEG device can detect delirium among elderly high risk patients • To test if a simplified device can detect delirium before clinical identification • 20 leads vs. 2 leads • Study design and participants ○ Study design prospective observational study, no intervention ▪ Simple EEG device monitoring twice a day ▪ Digital signal processing algorithm ▪ DRS, DOSS, and CAM-ICU twice a day ○ Study population (2016-2019) ▪ Initial two cohorts at high risk for delirium (orthopedic surgery pts and older adult general medicine pts) ○ Demographics of study cohort ○ Device: "Palm-sized" device and put a few electrodes on forehead
31:46	**EEG signals and spectral density analysis** • Example of data • BSEEG score—time series: the higher you go, there is more slow waves ○ Comparing delirium case to non-delirium case
33:08	**Initial group analysis from 45 cases**

	• Can see the difference between delirium and non-delirium
	• ROC analysis from test dataset
	  o Chose BSEEG score of 1.44 as the cut off (positive >1.44, negative<1.44)
	• Validation 1 from inpatient
	• Validation 2 from ER
	• Validation 3 from ECT
	  o ECT case monitoring over 2 hours

34:40	**New device tested** • More user friendly and simpler and had a thumb sized one • Validation 5 with a new device BSEEG score can quantify severity
35:10	**Can EEG predict delirium onset?** • Negative case • Positive case (EEG score changes 2 days earlier)
36:03	**Delirium, poor outcomes, and EEG** • Infographic of this relationship→ goes back to the question if EEG can predict outcomes?

36:29	**Outcomes and BSEEG score**
	• LOS and BSEEG scores were significantly correlated
	• Discharge outcome and BSEEG scores were significantly associated
	• Delirium and mortality
	• Can EEG predict mortality?
	  o BSEEG low vs. BSEEG high
	• Power of objective phenotyping
	  o Clinical category vs. EEG category
	• Dose dependent effect (BSEEG low vs. BSEEG middle vs. BSEEG high)
	• EEG x Delirium category and Mortality (purple= Delirious and EEG positive; blue= delirious but EEG negative; orange= not delirious and EEG negative; green=not delirious but EEG positive)
	  o Consistent with hospital mortality→ EEG matters!

40:47	**"Diffuse slowing" in EEG finding and mortality** • Normal vs. diffuse slowing
41:25	**Dementia and BSEEG** • Orange= no dementia & low BSEEG; Green= no dementia & high BSEEG; Blue= dementia & low BSEEG; Purple= dementia & high BSEEG
42:15	**Sepsis and BSEEG** • Was able to differentiate mortality, dose-dependent manner
42:45	**Another replication with a new device** • Validated with 1,077 subjects • All delirious patients are not the same • Motor subtype? o Hypo-active vs. Hyper-active

44:07	**Circling back to beginning of Gen's talk**
	• Imagination of family member in hospital
	• Question:
	  o Why do we measure blood pressure?
	  o How about glucose?
	  o **Based on this data why not BSEEG?**

44:27	**Summary** • Delirium is a dangerous condition • Early detection is vital for better outcomes • Current methods are not practical

	• Simplified EEG can detect delirium early • Easy to use for busy hospital settings • This approach would benefit patients, physicians, hospitals, and health economy
44:50	**Future Directions** • I envision this BSEEG score to be used as "next vital sign". Used every day, every patient, in the hospitals, clinics, and nursing homes. • A thumb-size, newer device being tested • Real goal is to bring this technology to the patients • Peri-operative protocol in 2030? (getting baseline BSEEG and then post-op BSEEG)
46:32	**Questions and Answers**