Brain function monitoring using trend-assisted qEEG, seizure detection, and spike detection: Case studies

Mark L. Scheuer, M.D.
Persyst Development Corporation

University of Pittsburgh
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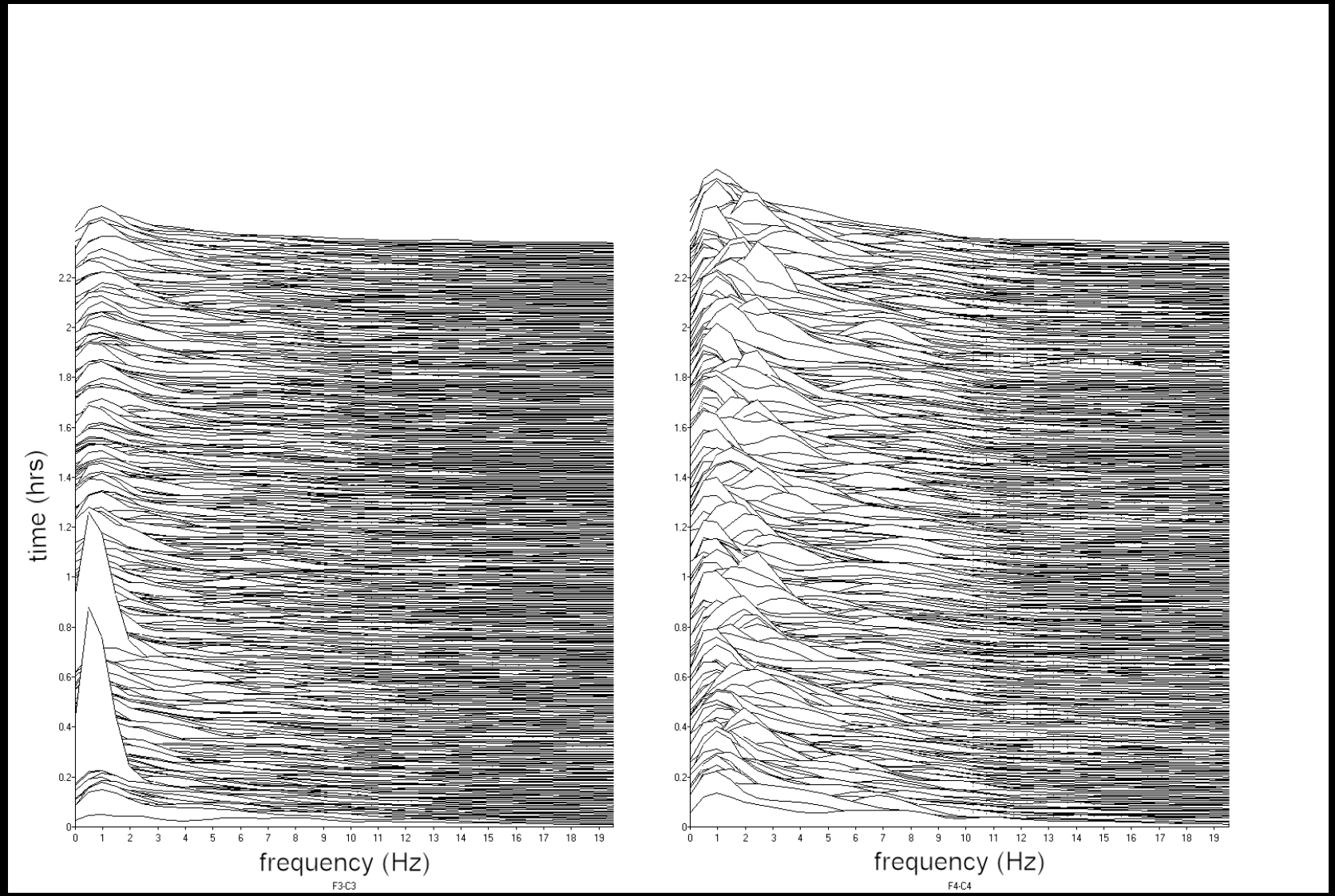
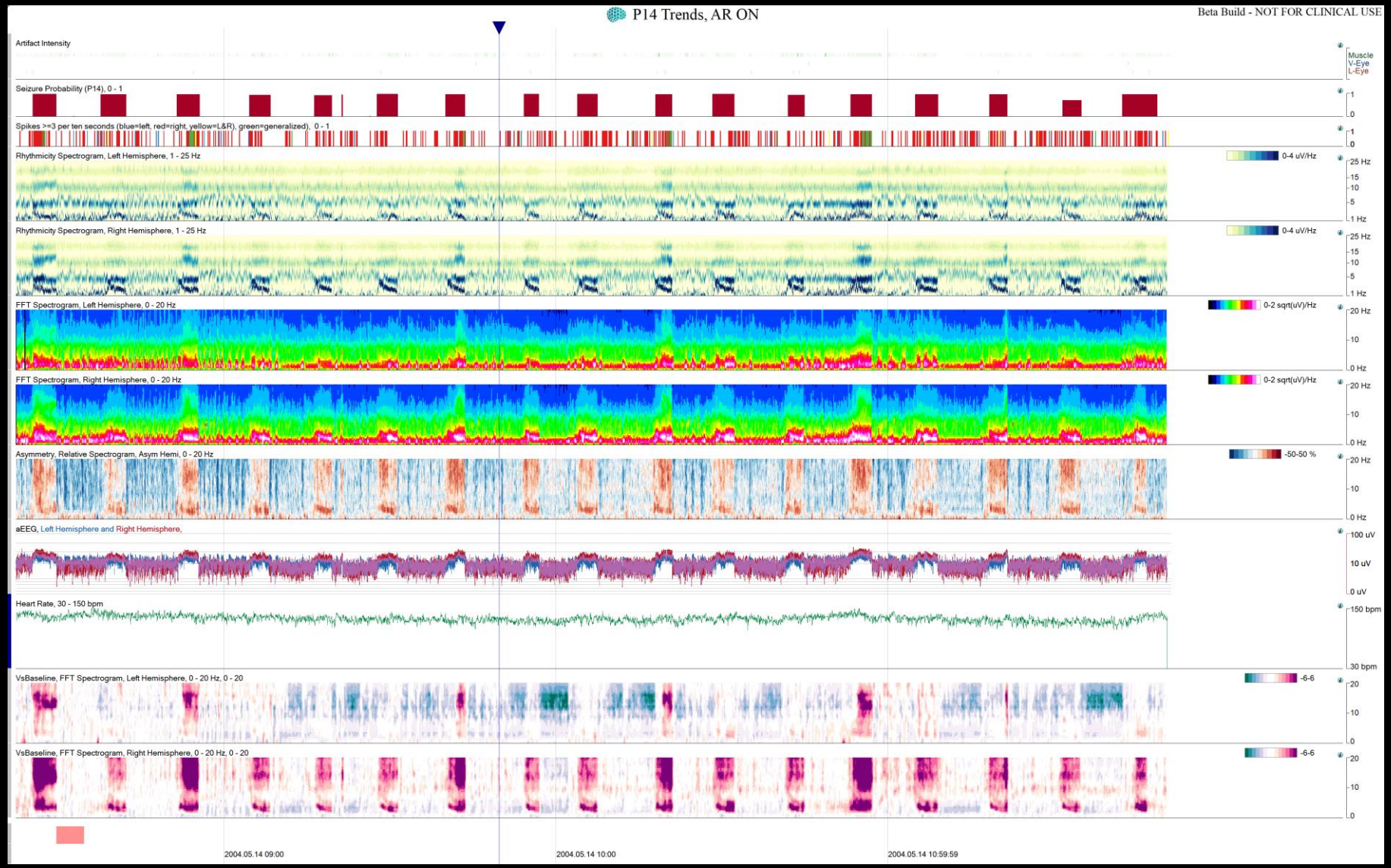
Evolution of continuous brain function monitoring (EEG) over the last 30 years

- 1985: Neuro exam plus two channel compressed spectral array, no access to stored EEG waveforms

Hidden line compressed spectral array from comatose patient having frequent clinically silent seizures



Jump forward 35 years: Obtunded adult post-liver transplant: 4-hour EEG trend view, P14 sz detector (2020)



17 of 17 (100%) seizures were automatically detected (one other brief possible sz also tagged). All these seizures show clear-cut, stereotyped, and distinctive EEG trend changes. Fairly frequent right spikes or sharps are present. vsBaseline trends show clear variations in seizure spread patterns.

Evolution of continuous brain function monitoring (EEG) over the last 30 years

- 1985: Neuro exam plus two channel compressed spectral array, no access to stored EEG waveforms
- 1987: short-term continuous EEG (paper) for hours
- Early 1990s: advent of digital EEG/ digital video-EEG; limited storage; short-term ICU monitoring
- Late 1990s: continuous digital EEG (and vEEG) with density spectral array; all EEG waveforms available; long-term ICU monitoring begins
- 2000-2020: increasingly sophisticated real-time EEG analytic software, including seizure detection, artifact reduction, spike detection, and EEG trends (e.g., FFT, rhythmicity, asymmetry, aEEG) reflecting key EEG features utilized by clinical neurophysiologists

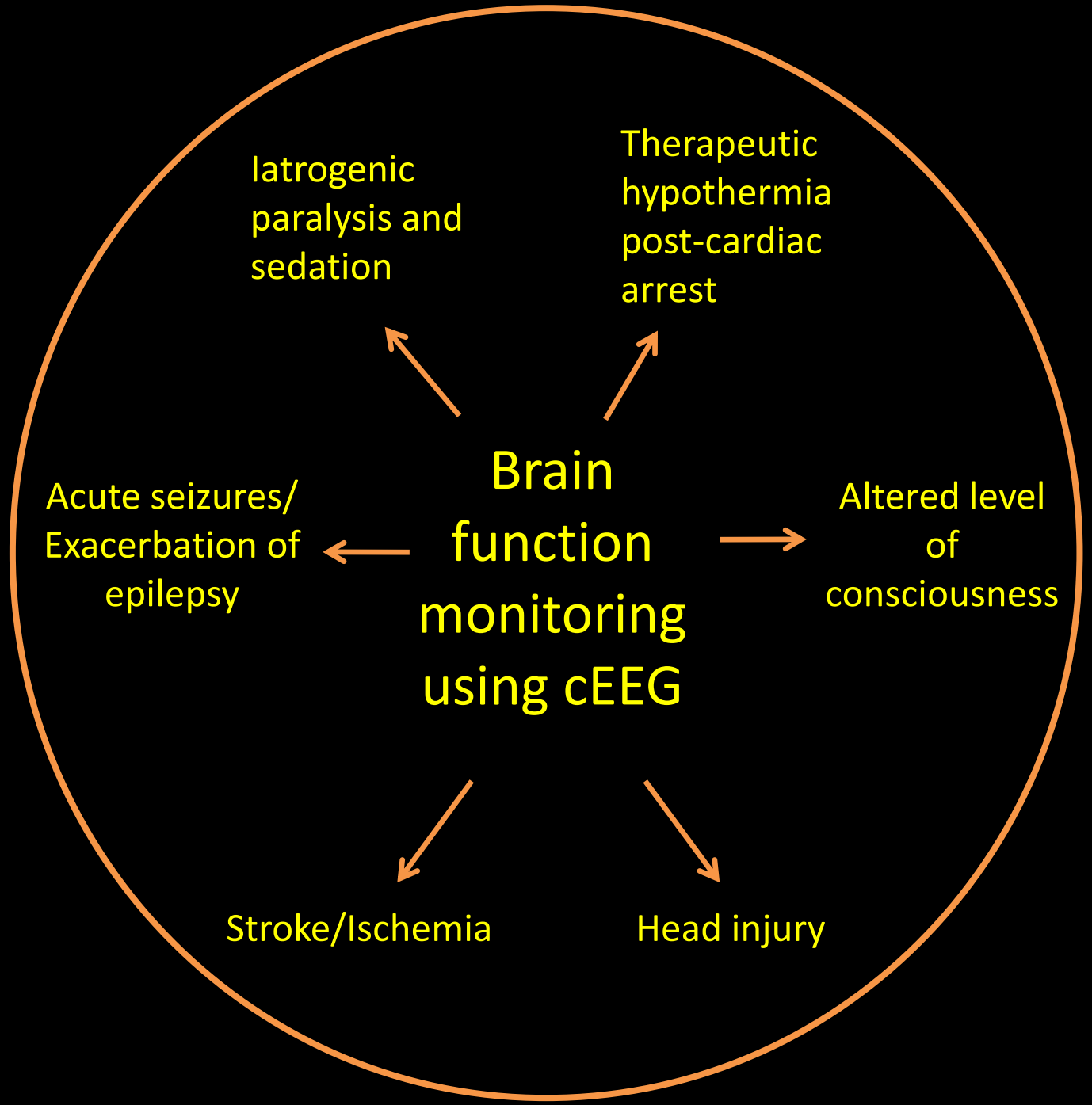
EEG advantages for brain function monitoring

- Known EEG changes correspond to a variety of physiological state changes and pathologies
  - e.g.: sleep states, seizures, metabolic encephalopathies, focal lesions, seriously elevated ICP, drug effects
- EEG has excellent temporal resolution
- EEG (scalp) has good spatial resolution (regional)
- EEG can be performed continuously at the bedside with minimal interference with other patient care functions
- Performing an EEG is safe (no transport of seriously ill patients for diagnostic testing)

Recent meta-analysis regarding monitoring for seizures using EEG

- Limotai C, Ingsathit A, Thadanipon K, McEvoy M, Attia J, Thakkinstian A. How and Whom to Monitor for Seizures in an ICU: A Systematic Review and Meta-Analysis. Crit Care Med. 2019;47:e366–73.

- Seizures in the critically ill are common and usually non-convulsive or without physical signs, including non-convulsive status epilepticus


Iatrogenic paralysis and sedation
Therapeutic hypothermia post-cardiac arrest
Acute seizures/ Exacerbation of epilepsy
Brain function monitoring using cEEG
Altered level of consciousness
Stroke/Ischemia
Head injury

Why use EEG trending and computerized EEG assessments to assist EEG review?

- *Help to focus initial or intermittent review:* rapid identification of major findings like seizures, spikes, and important alterations in the EEG

Why use EEG trending and computerized EEG assessments to assist EEG review?

- *Provide a map of (often complicated) EEG-evident brain function changes*
  - Continuously monitoring a group of patients with diverse dynamic alterations in brain function is challenging
  - EEG trends provide a map of many such changes and help to reorient a clinician to the particulars of each case during repeated review

Why use EEG trending and computerized EEG assessments to assist EEG review?

- *Provide an independent assessment of the EEG data* using computerized detections and qEEG trends
  - Cross-check that all seizures and important changes were recognized
  - Cross-check that all spike types were recognized, and rare epileptiform abnormalities weren’t missed

Why use EEG trending and computerized EEG assessments to assist EEG review?

- *Provide an overview of long-term EEG activity* via EEG trend graphs
  - slowly altering patterns can be difficult to track during page-by-page EEG review (e.g., quantity of suppression-burst, frequency of seizures, or slowly deteriorating hemispheric function)

Why use EEG trending and computerized EEG assessments to assist EEG review?

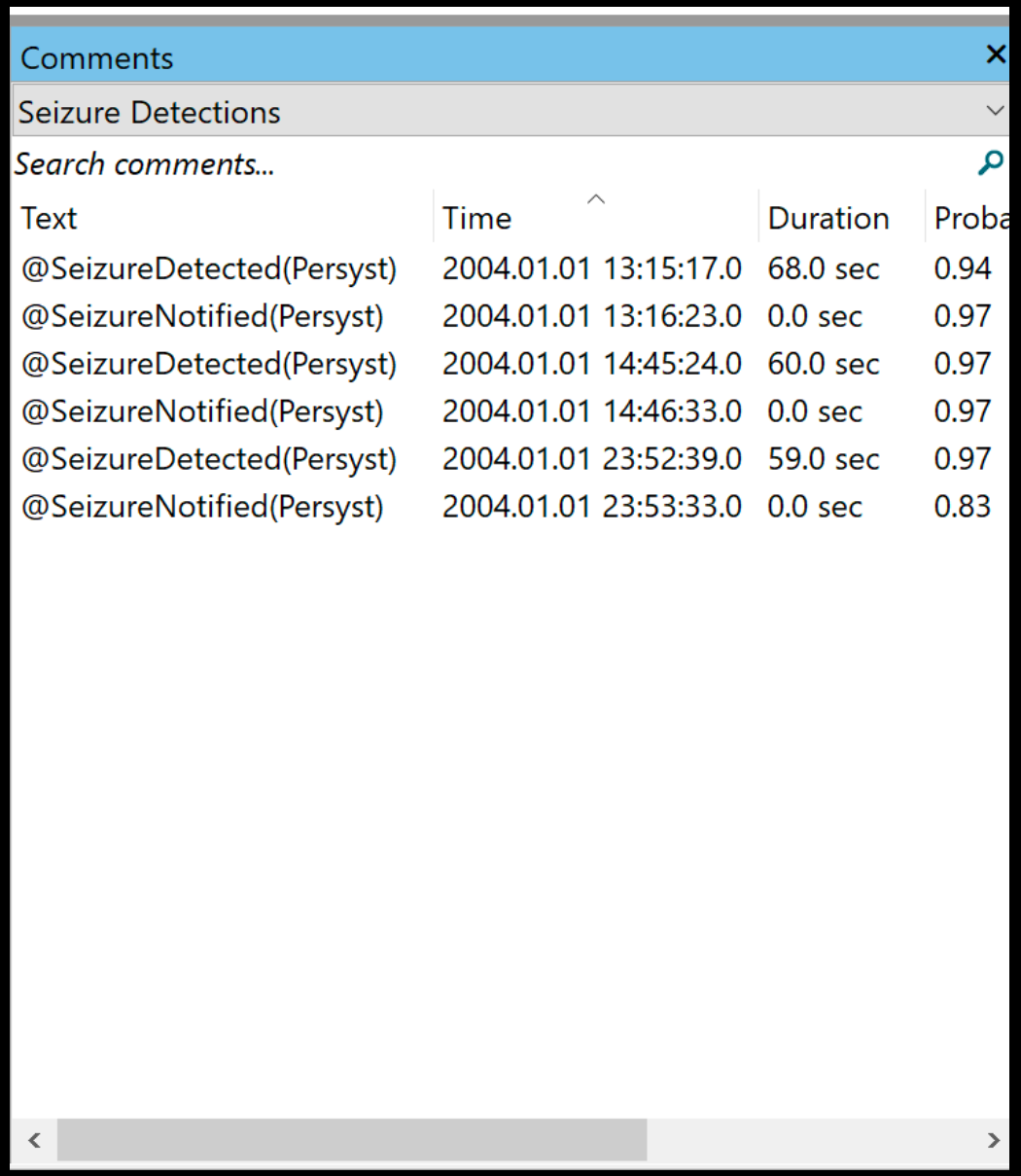
- *Get a long-term overview of electrode signal quality* via signal quality trends
  - Helps to improve the quality of continuous EEG recordings
  - Encourage assistance of ICU bedside staff in doing some simple electrode maintenance tasks

Case 1: John Doe

- Adult undergoing ambulatory EEG monitoring to assess episodes of altered awareness and confusion
- Initial outpatient EEG, awake and transiently drowsy, interpreted as normal

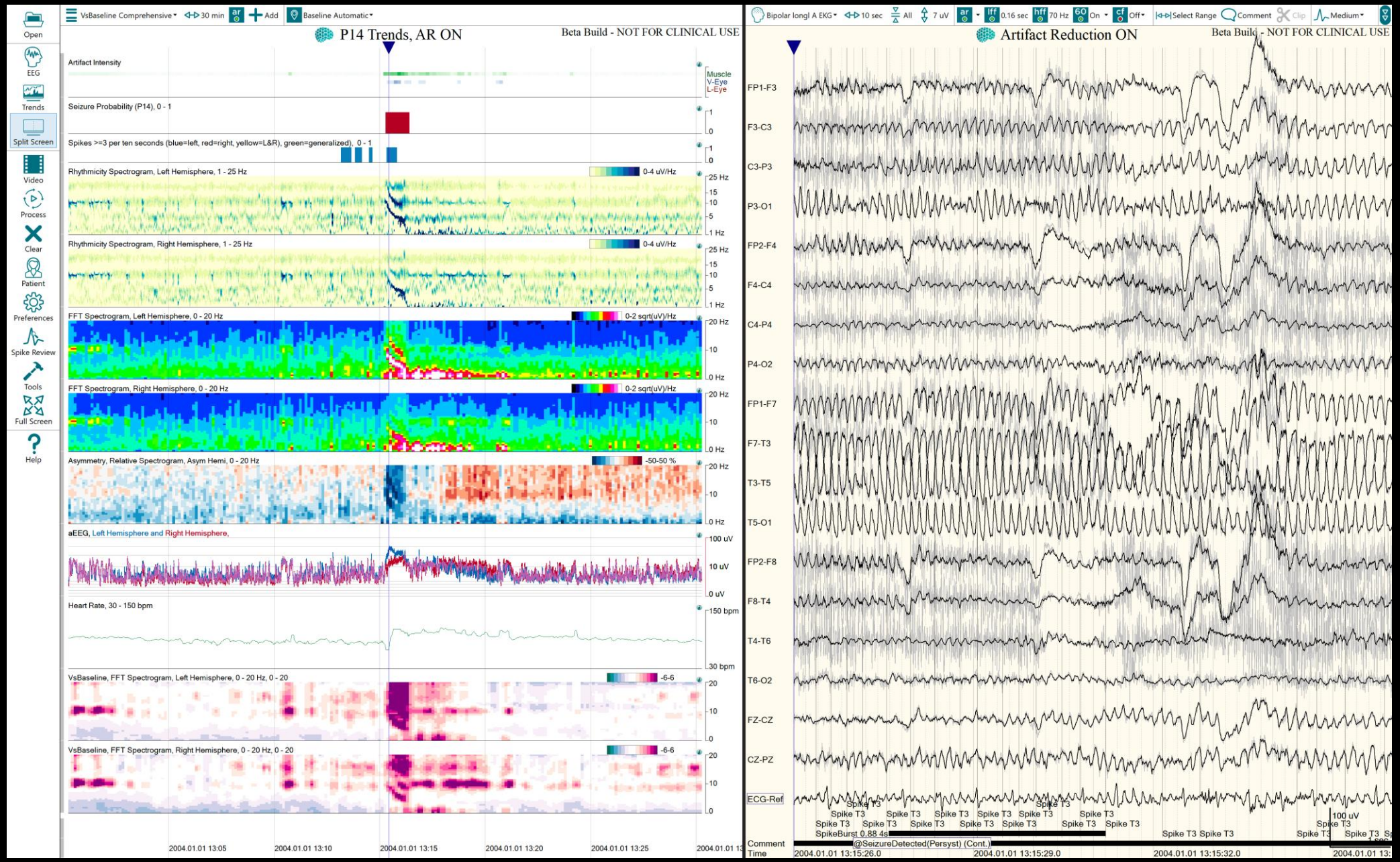
Initial view

Assess seizure detection list

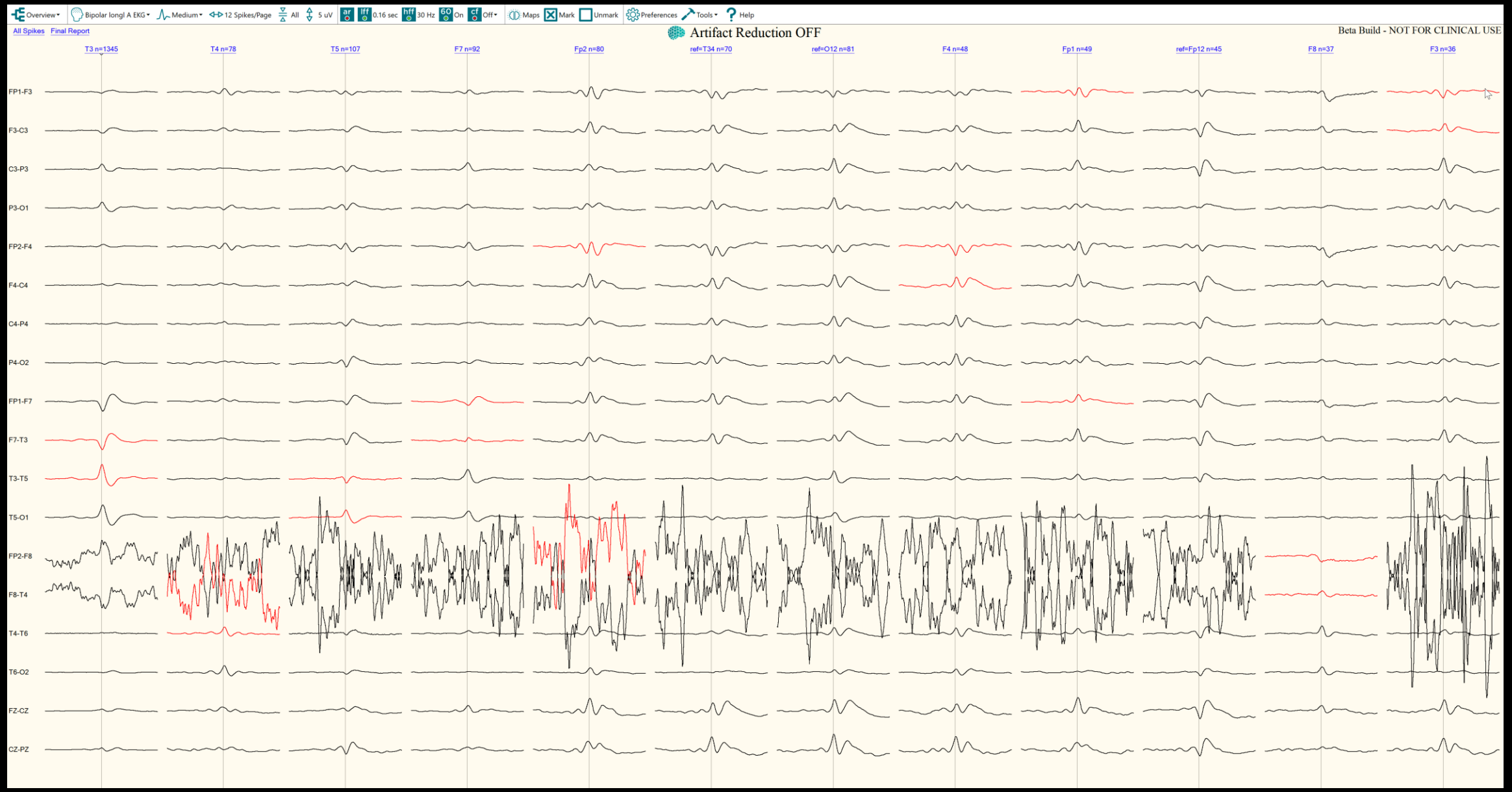


First sz detection: No pushbutton, event occurred during sleep, seizure disorder verified

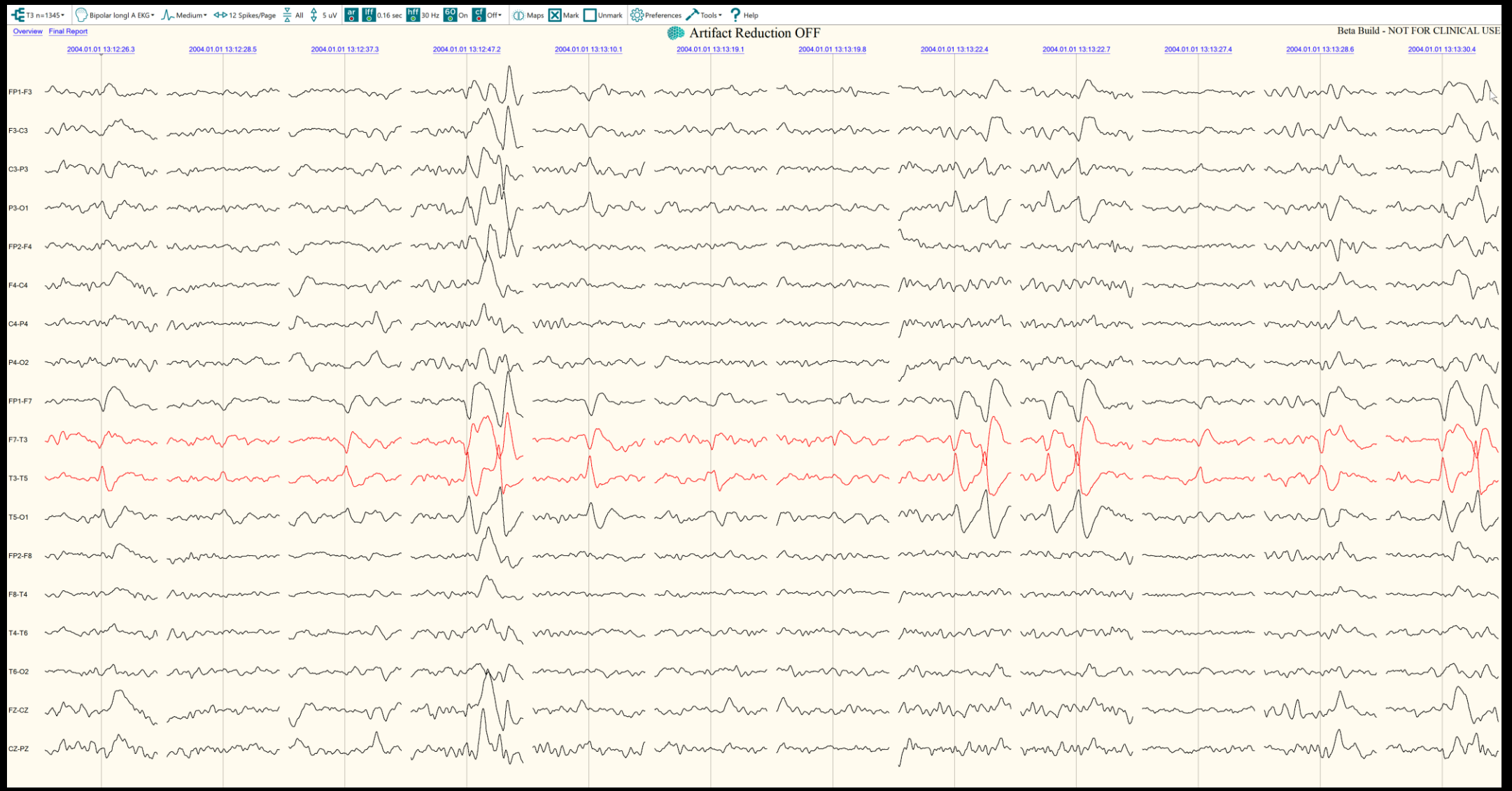
Two other detections showed similar ictal patterns; no other seizures identified on complete review of trends and EEG



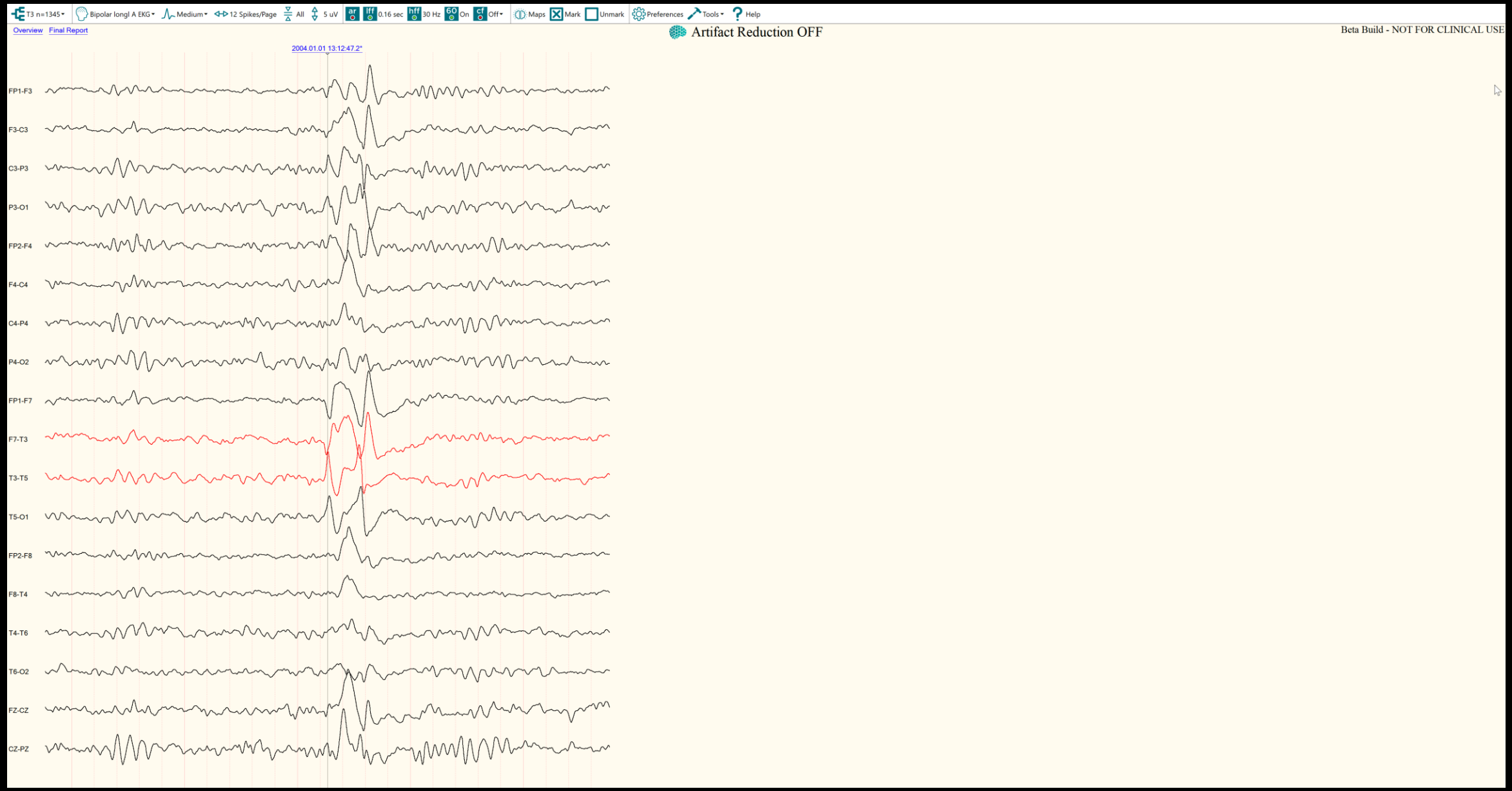
SpikeReview: Dominant left mid-temporal sharp wave focus evident



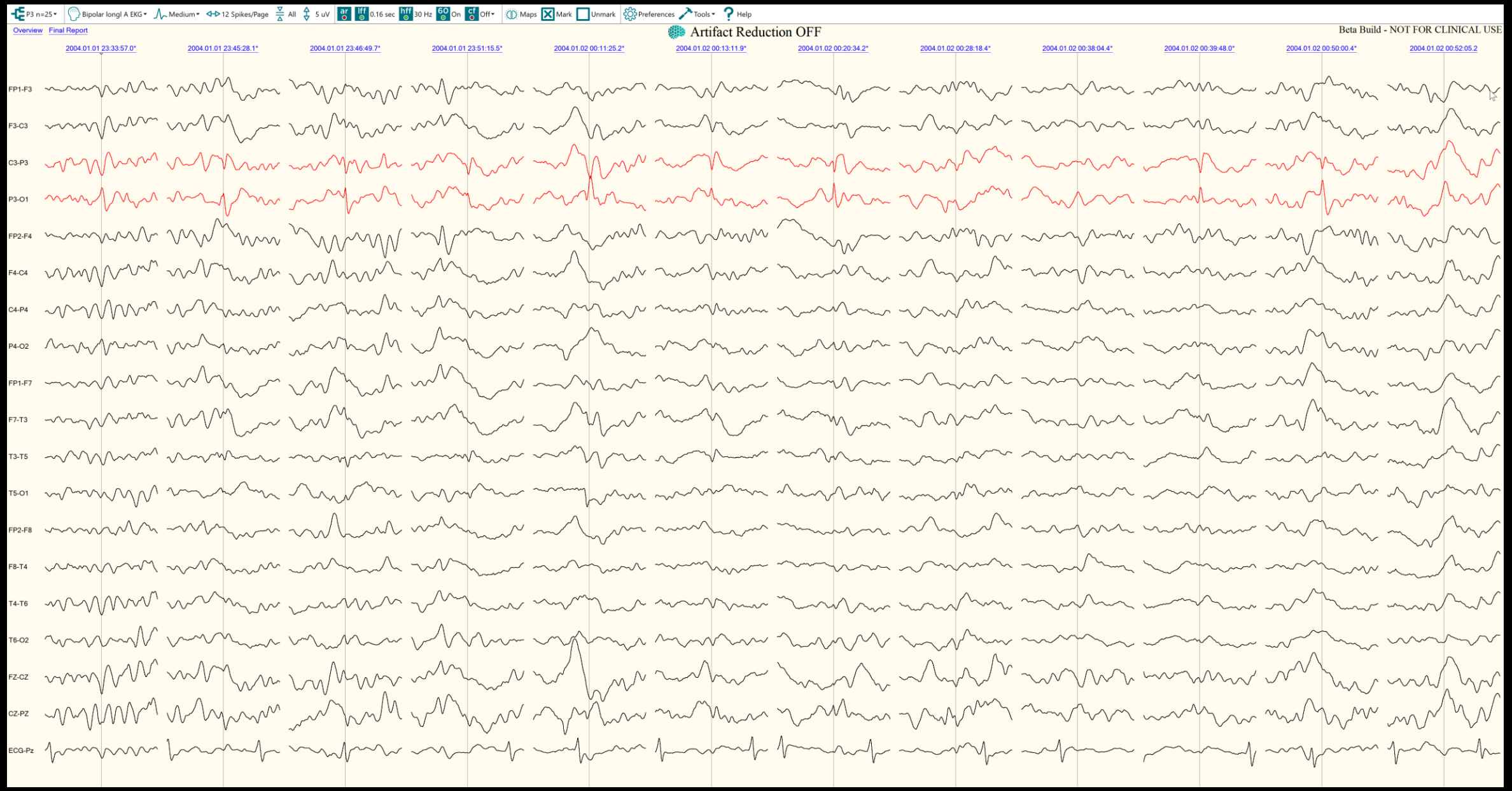
Results from one spike detection group shown arranged back-to-back in 1-sec. clips: T3 fcous



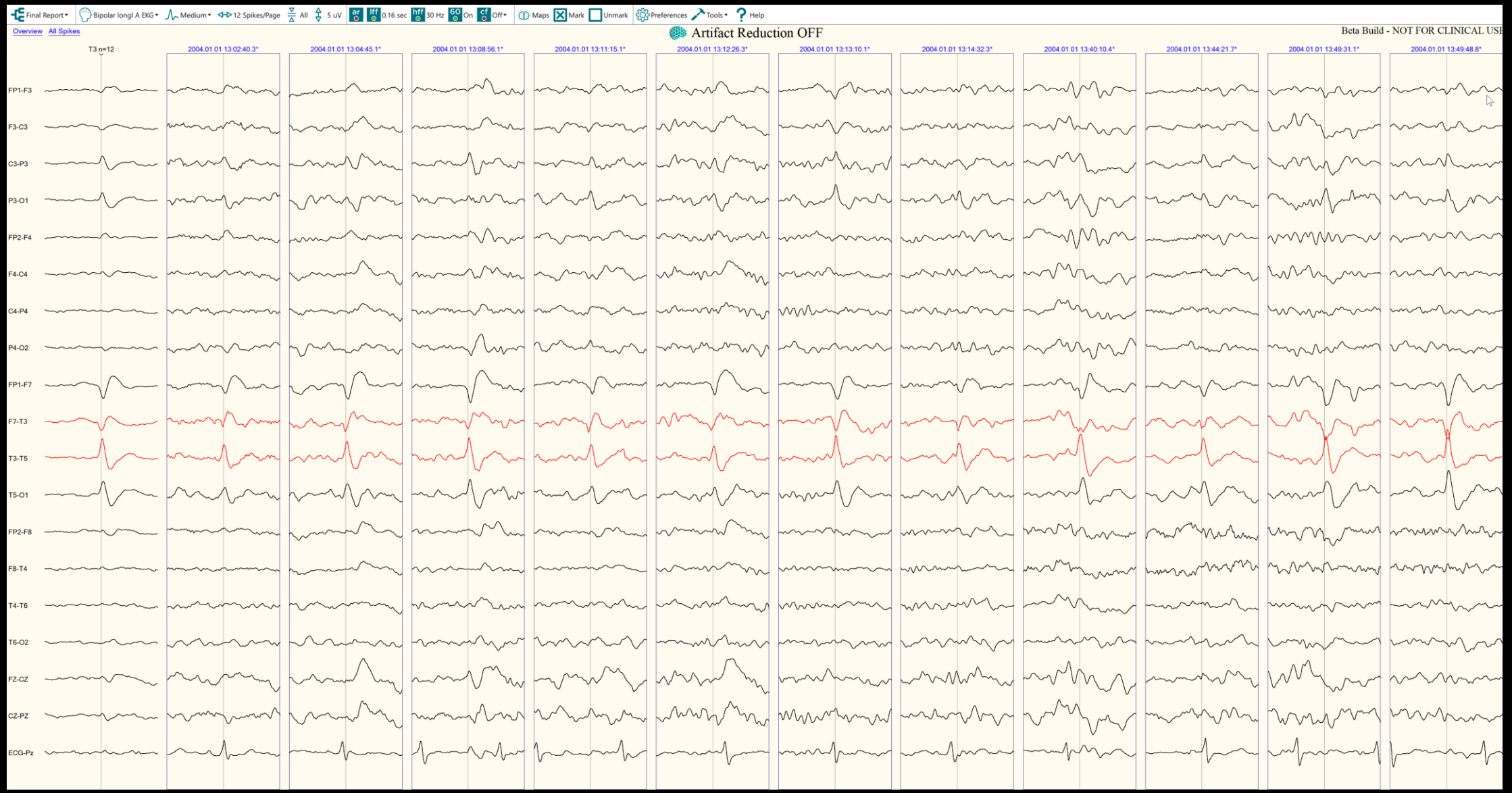
5-second view of a single detection (doublet spike)



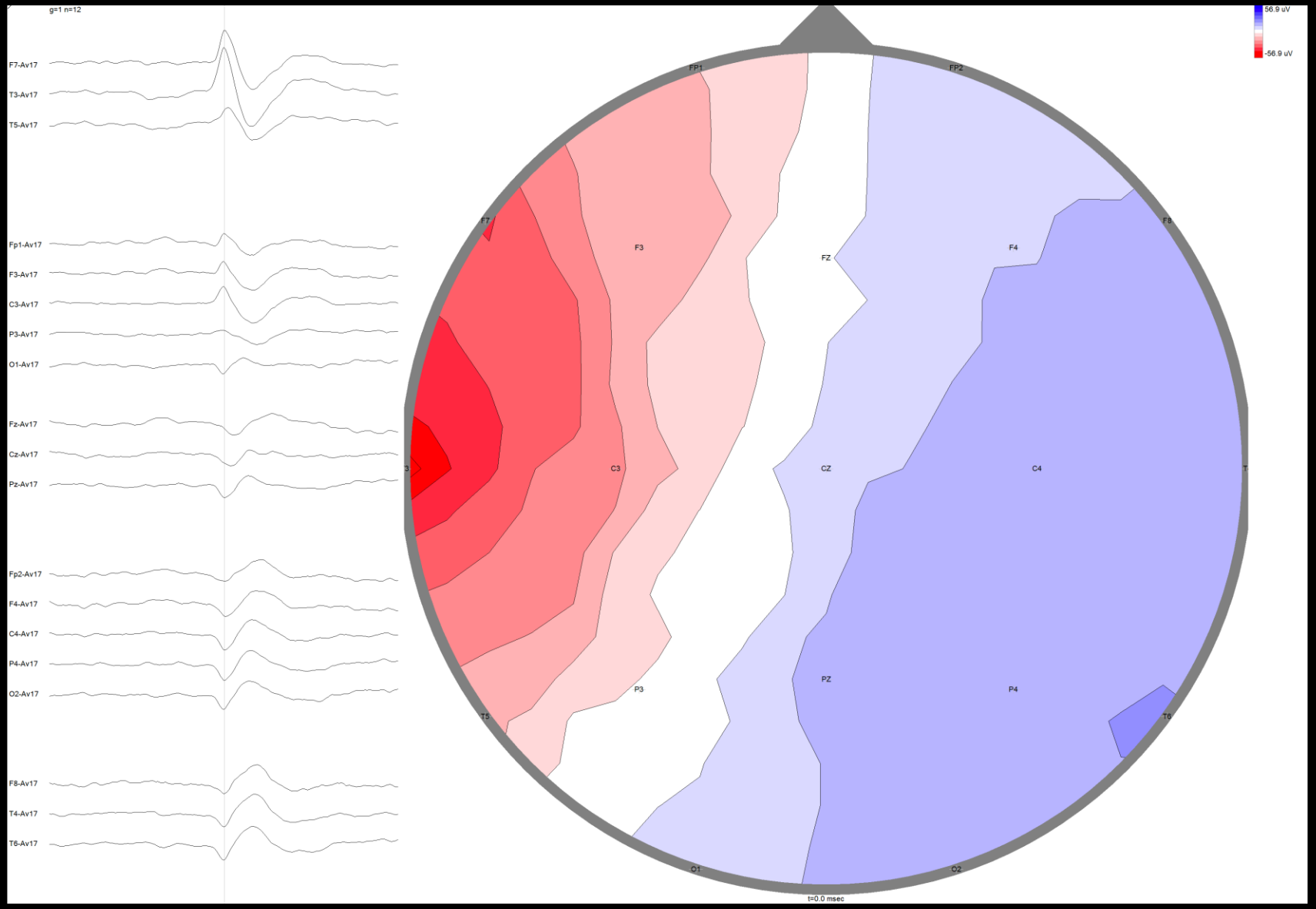
A second focus with much rarer P3 spikes



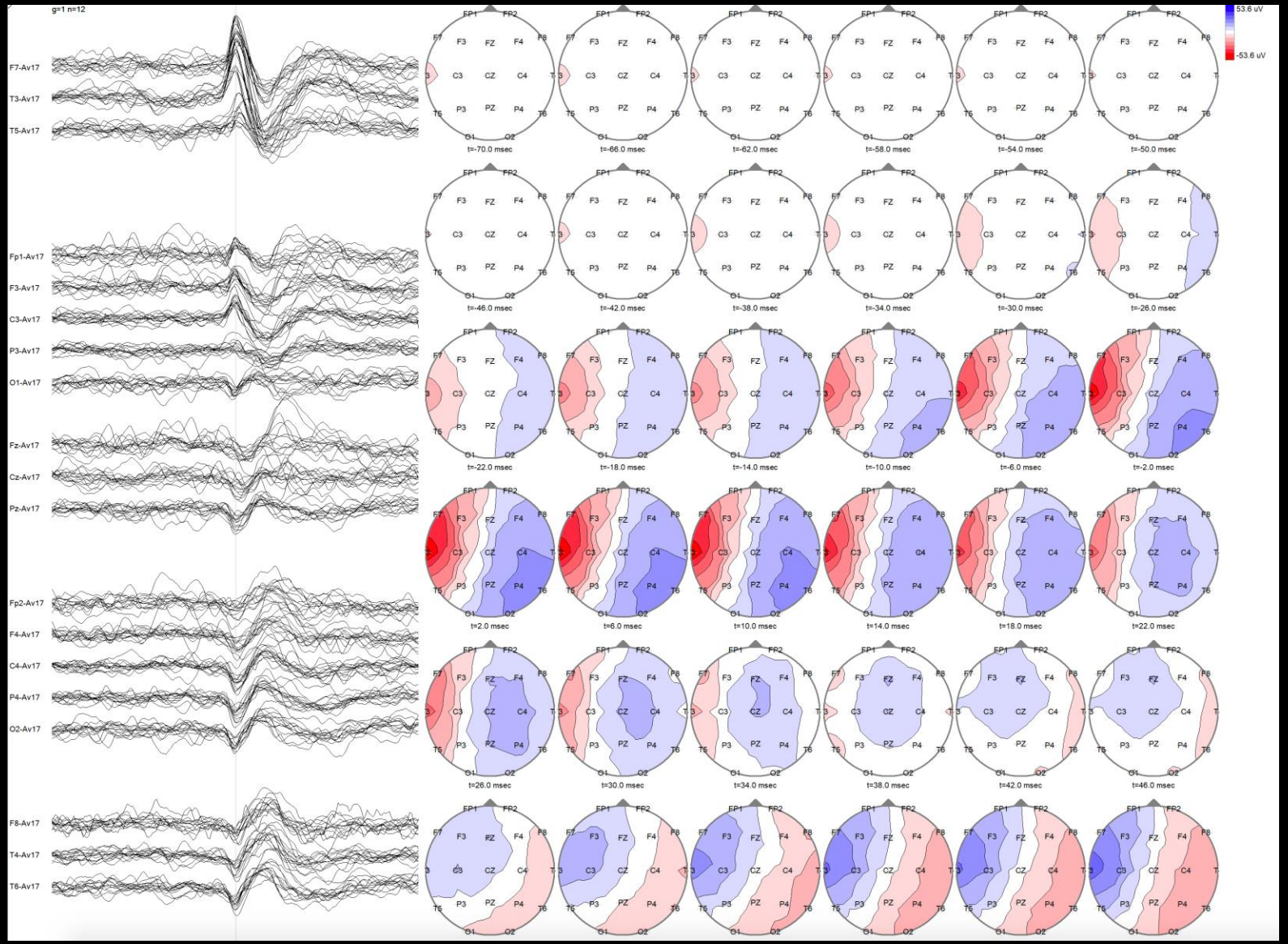
Final report view of hand selected mid-temporal exemplar epileptiform abnormalities



Voltage plot of 12 averaged T3 spikes at peak



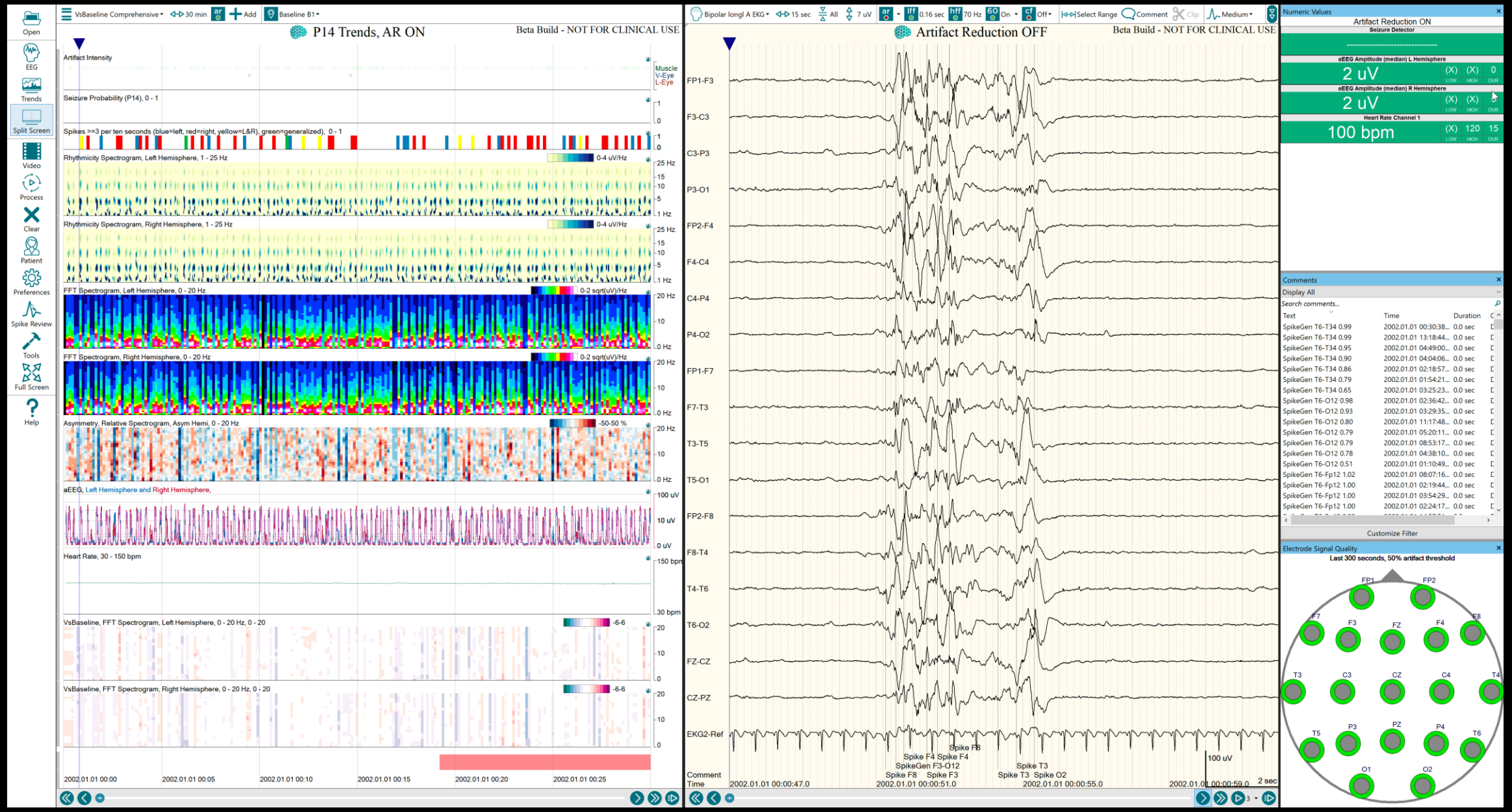
Voltage plot progression map (waveform displays overlay of 12 T3 spikes forming average of previous image); 4 msec. steps



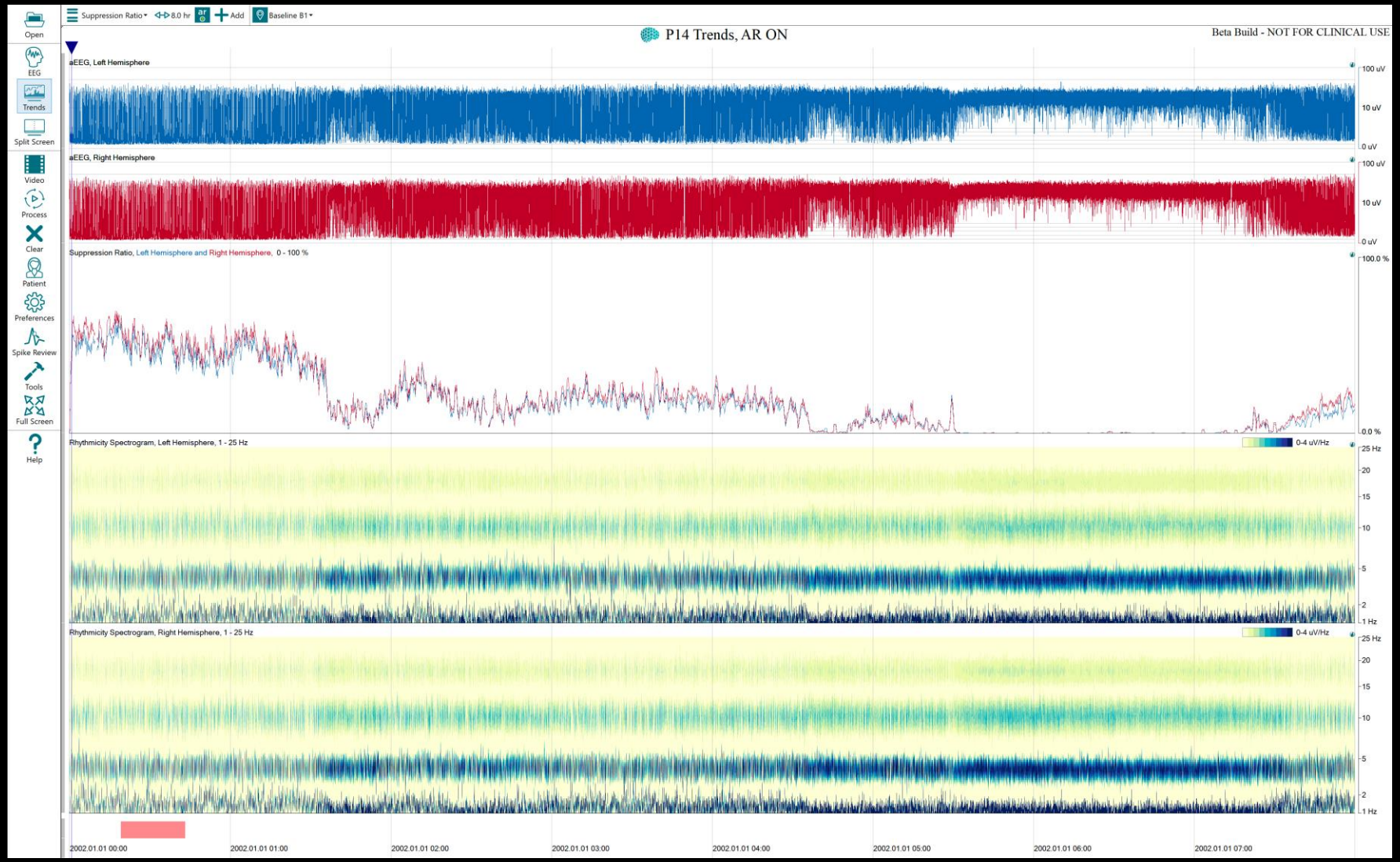
Case 2: Jane Doe

- Child with viral encephalitis
- Being treated with intravenous pentobarbital for difficult to control status epilepticus
- cEEG monitoring to assess course of treatment

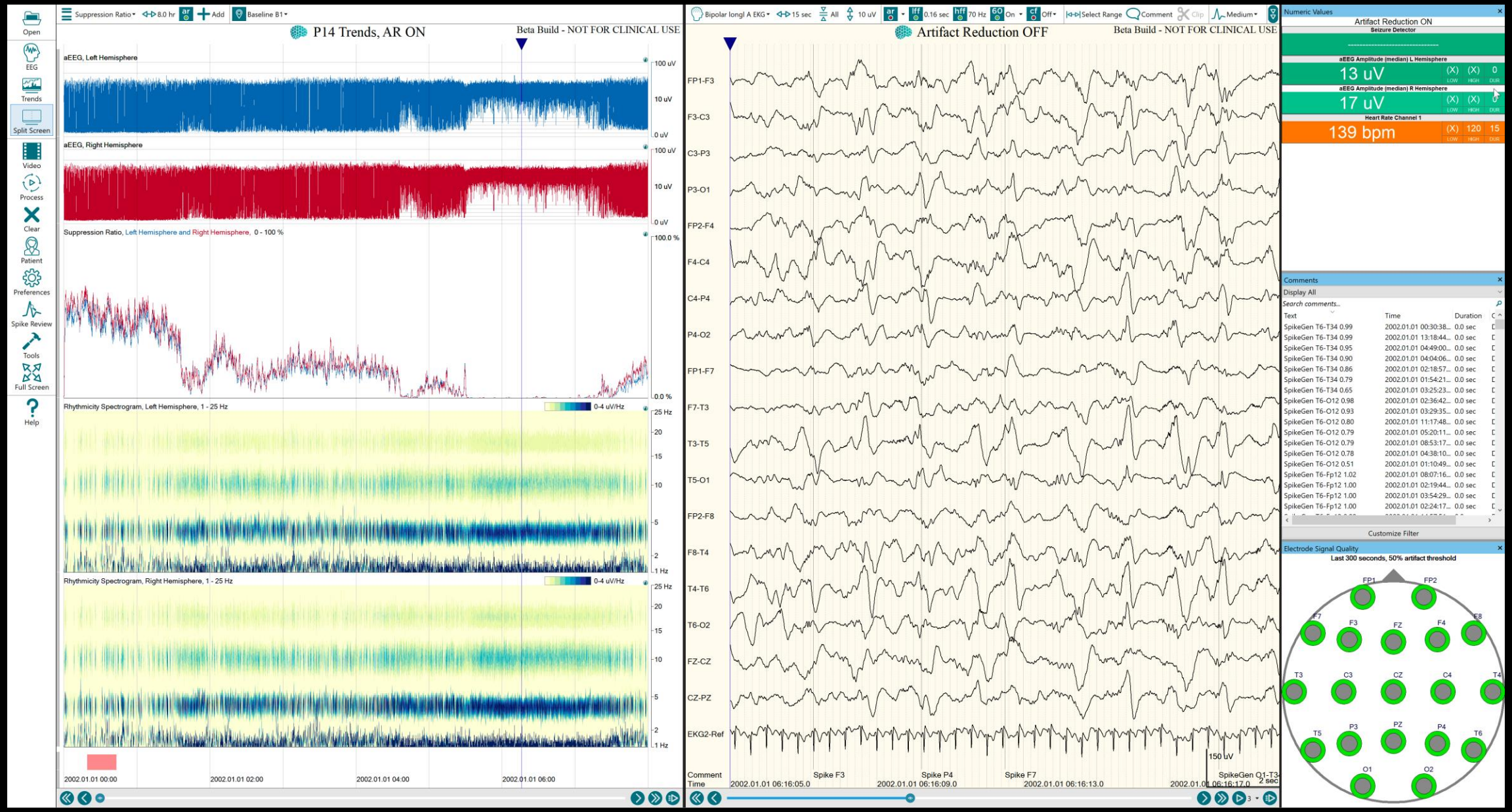
Suppression-burst pattern evident at onset of monitoring; 30-min. view



aEEG and Suppression Ratio trends show initial suppression-burst pattern and subsequent abatement of pattern on several occasions; 8-hour view



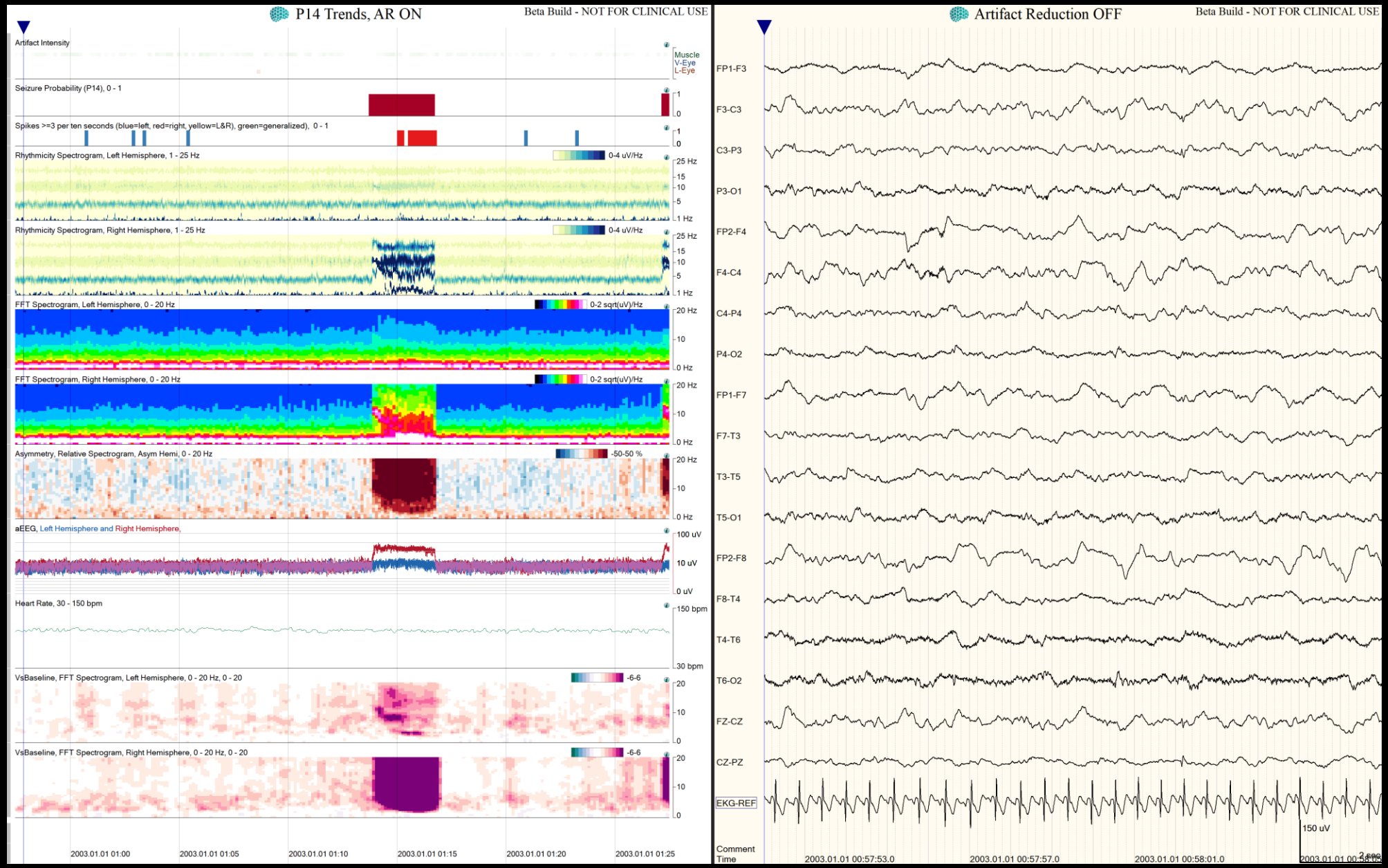
Split-screen showing 8-hour trends and continuous EEG



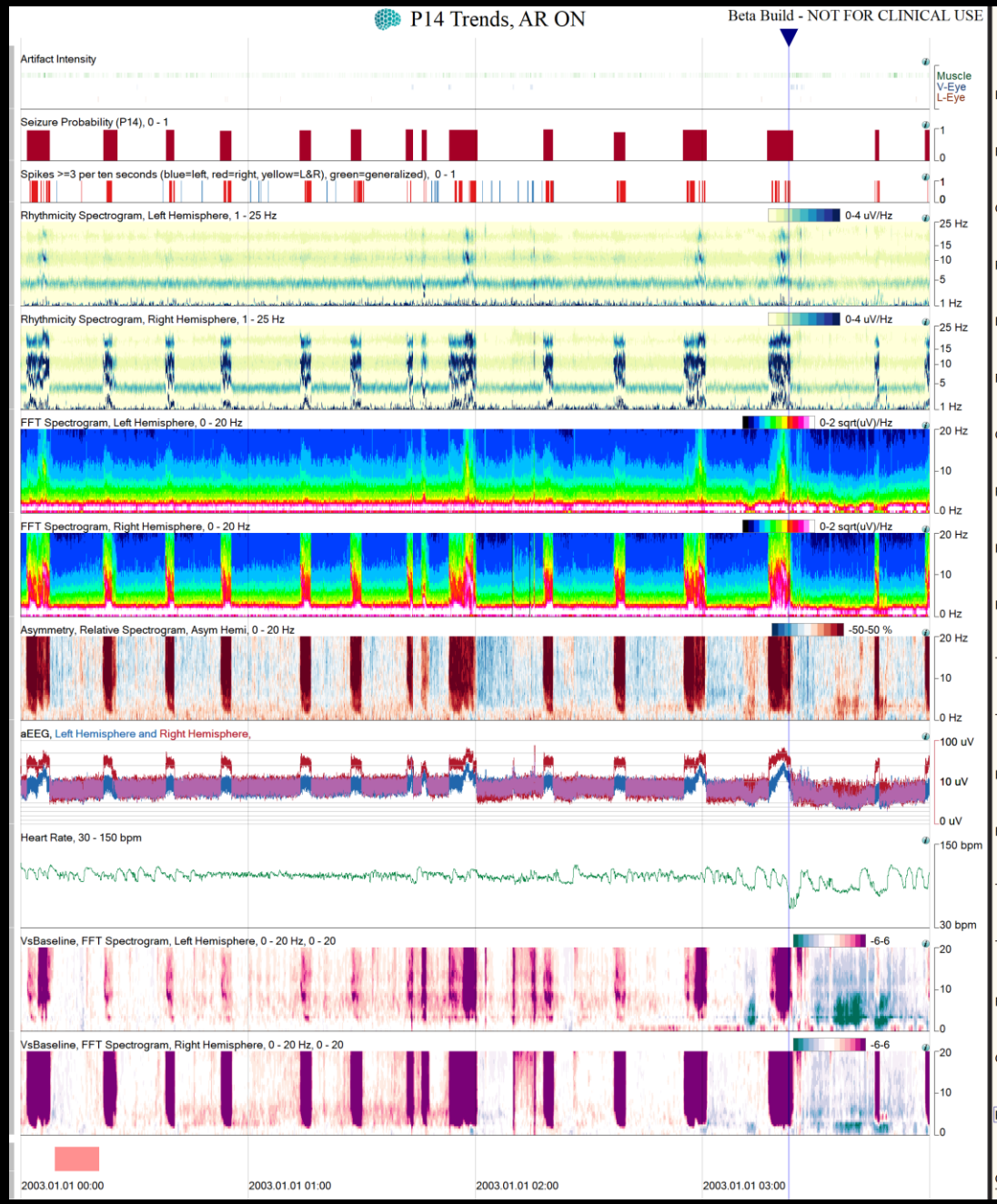
Case 3: John Smith

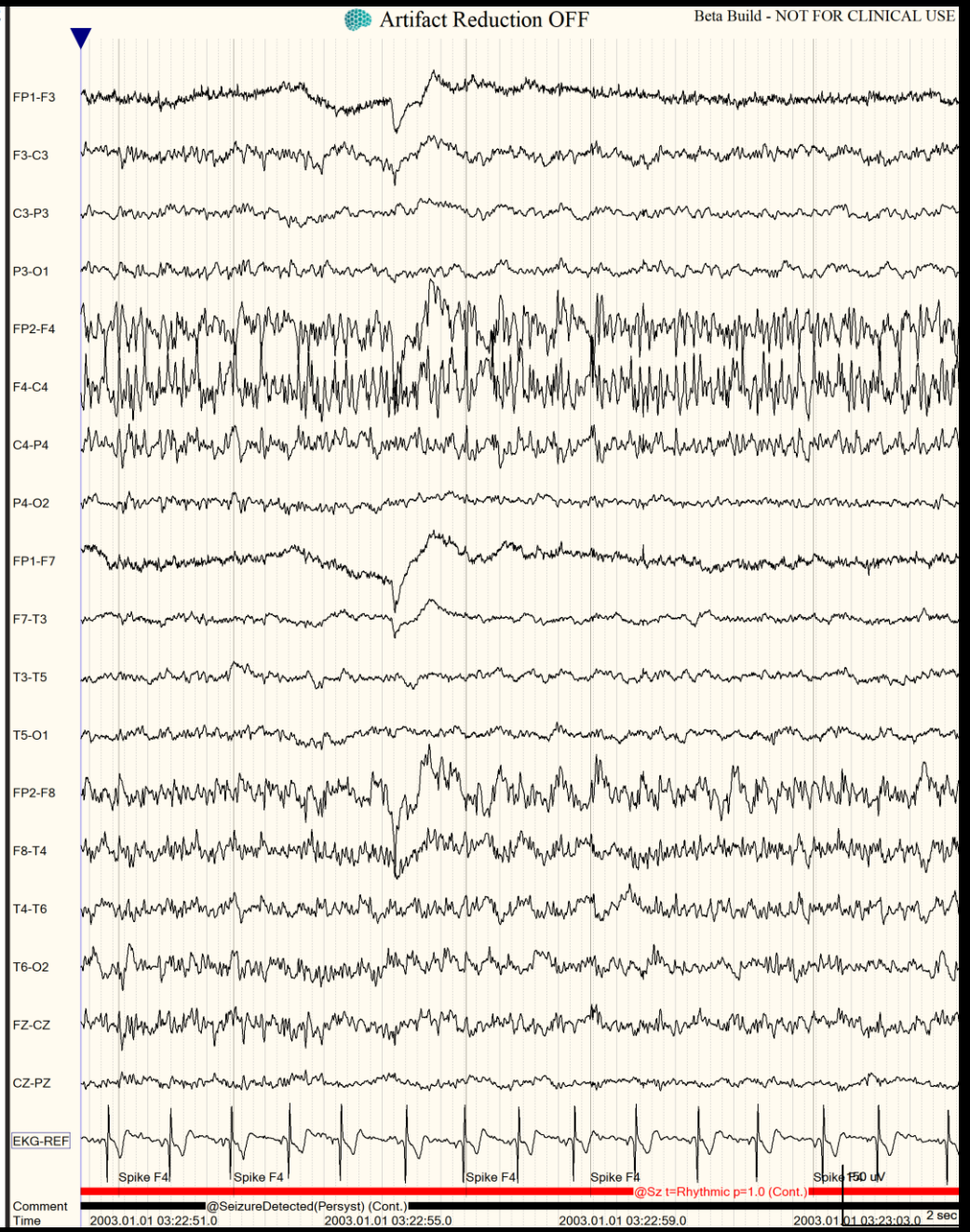
- Young adult with gradually progressive neurological disorder, cognitive difficulties, seizures, and a recent exacerbation of seizures
- In ICU due to tenuous condition, including pneumonia
- cEEG monitoring to assess efficacy of therapy

First half-hour monitoring shows a several minute-long seizure

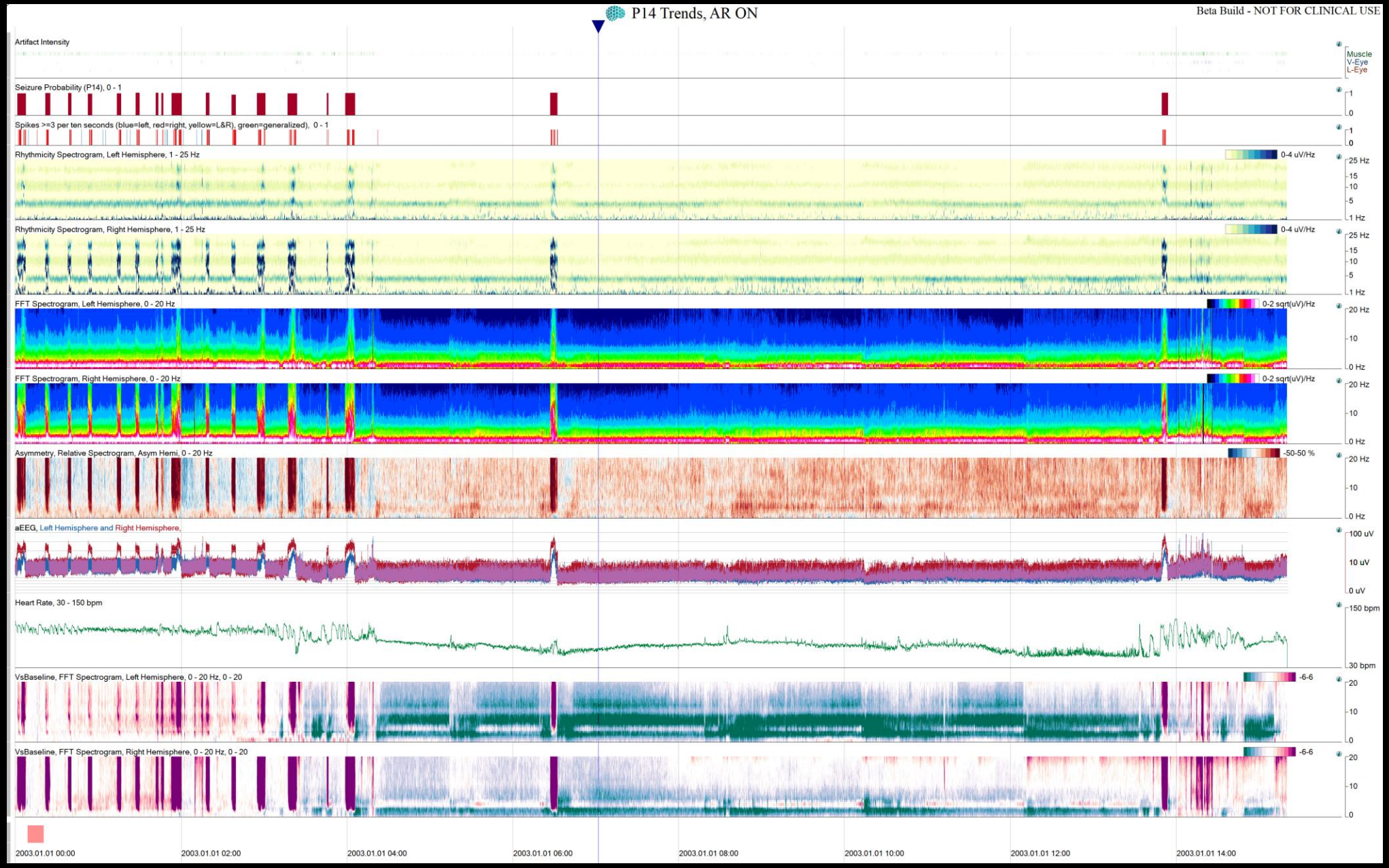


4-hour view: many R hemispheric seizures evident despite intensifying treatment; some spread to left





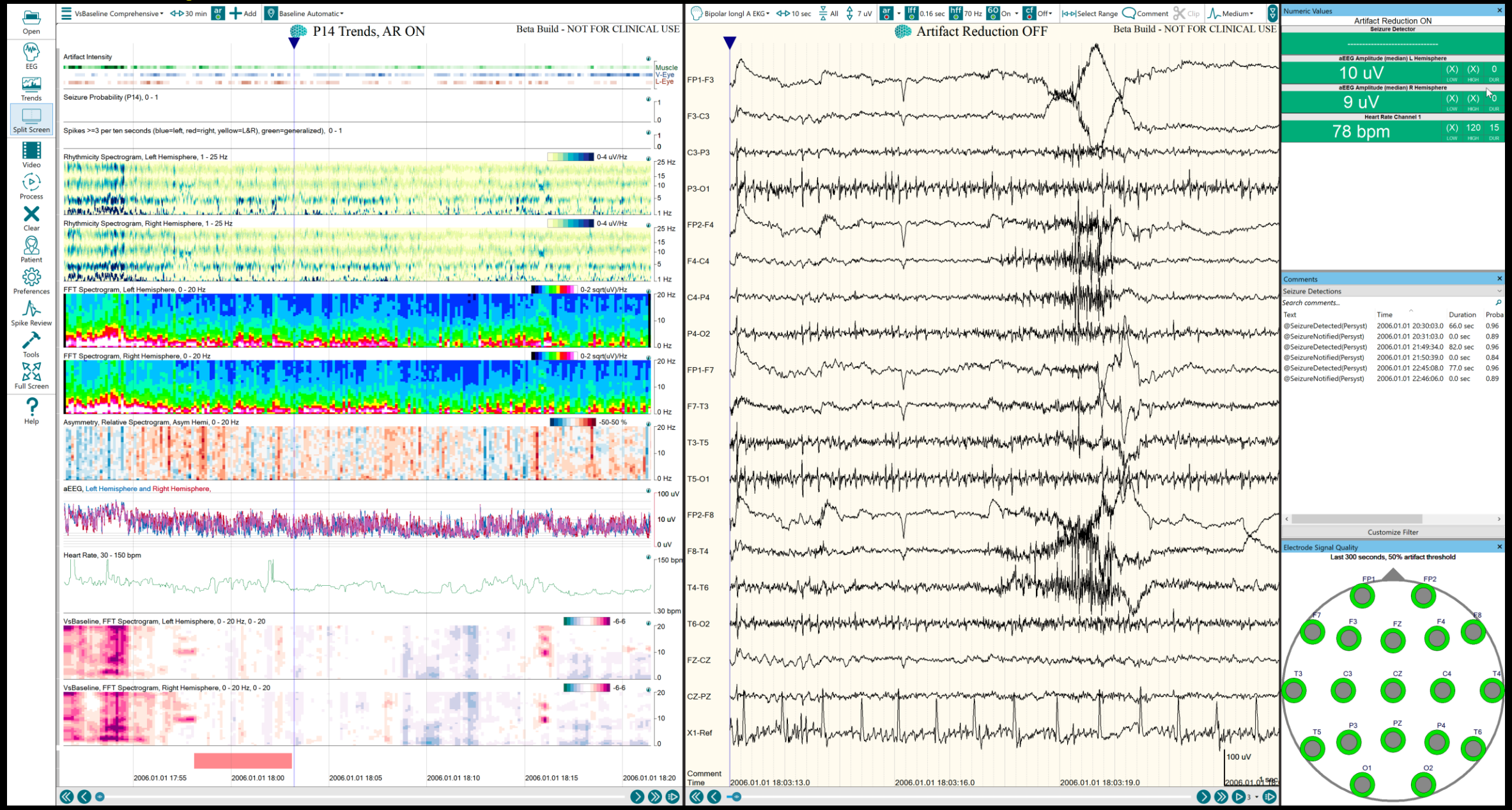
16-hour view of same case: seizures abated with further intensification of iv propofol, but still occasionally recurred with similar findings



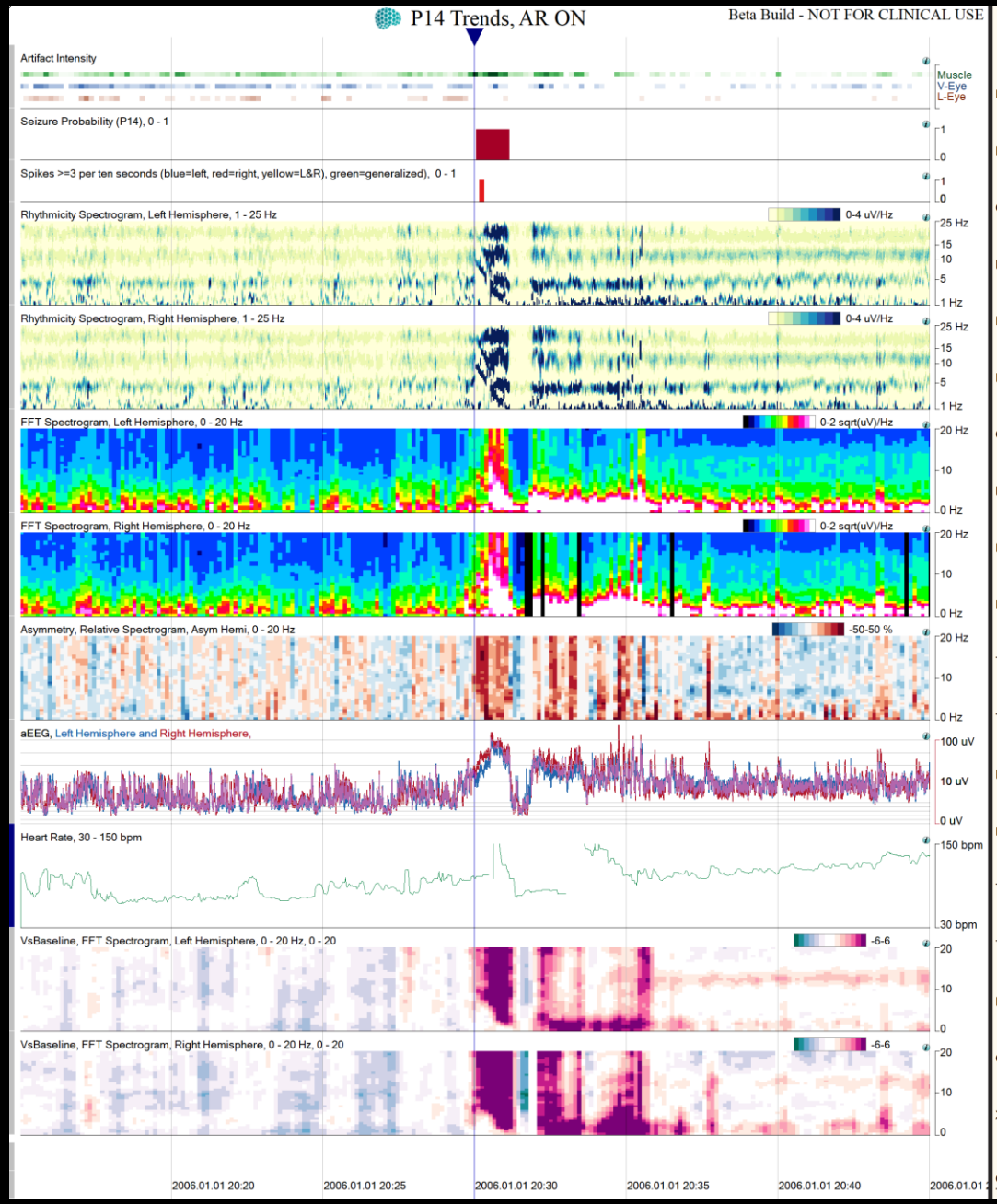
Case 4: Howard Hughsman

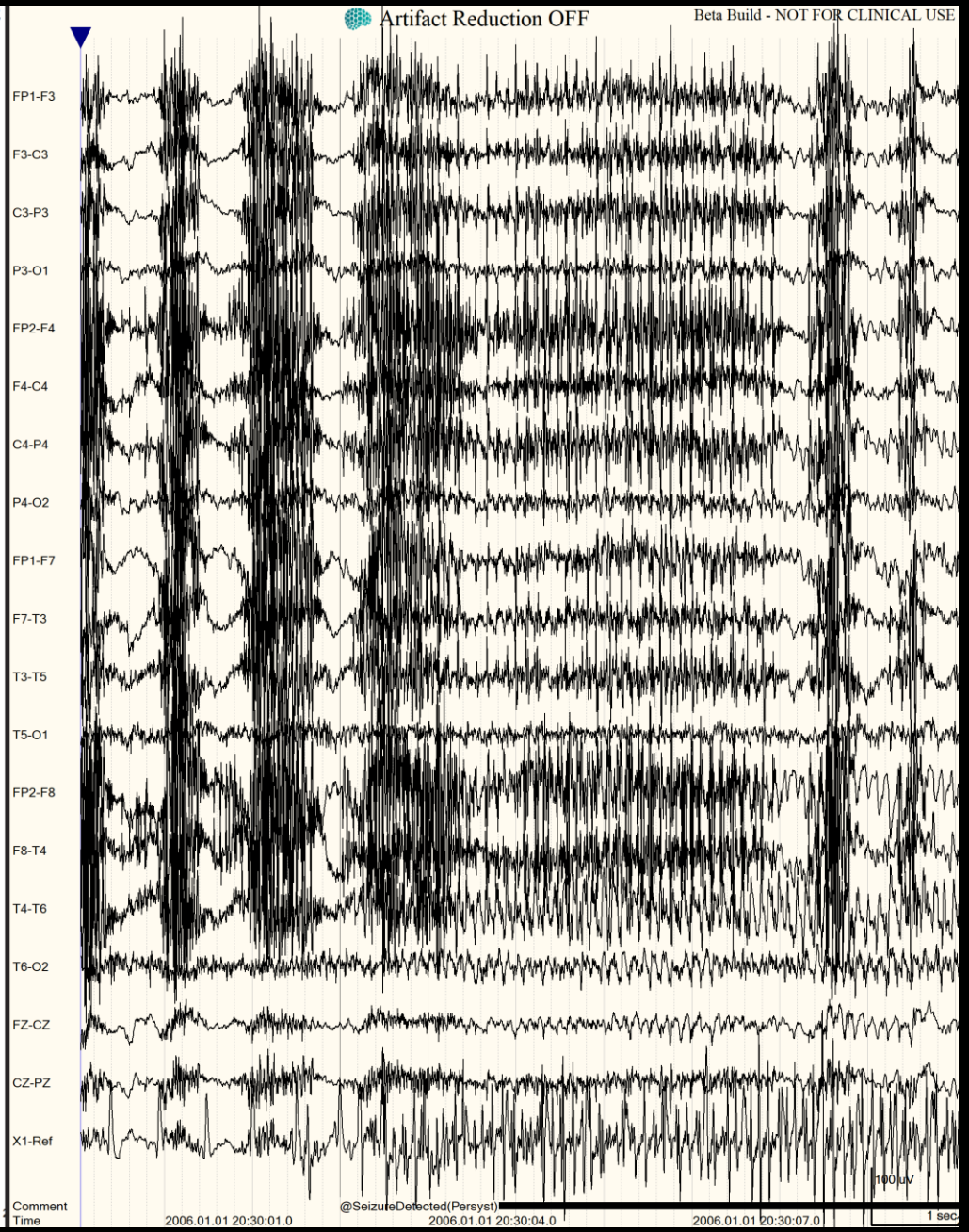
- Adult with seizures manifested as minutes-long episodes of impaired awareness since early teens
- Admitted to epilepsy monitoring unit for evaluation
- Antiseizure medications rapidly tapered in attempt to increase seizure frequency and record habitual seizures

Multiple seizure detections (see comment list)

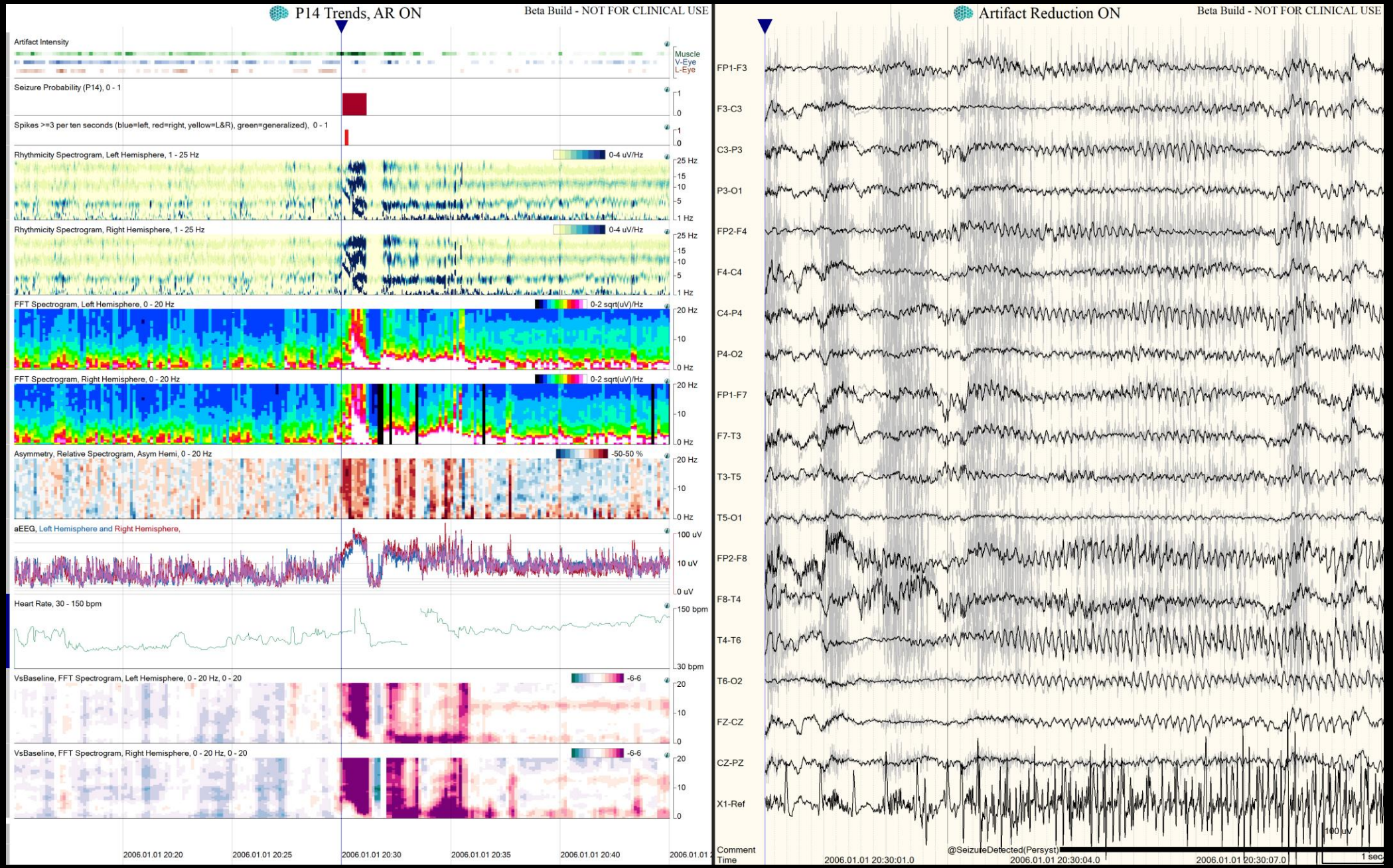


First seizure detection review

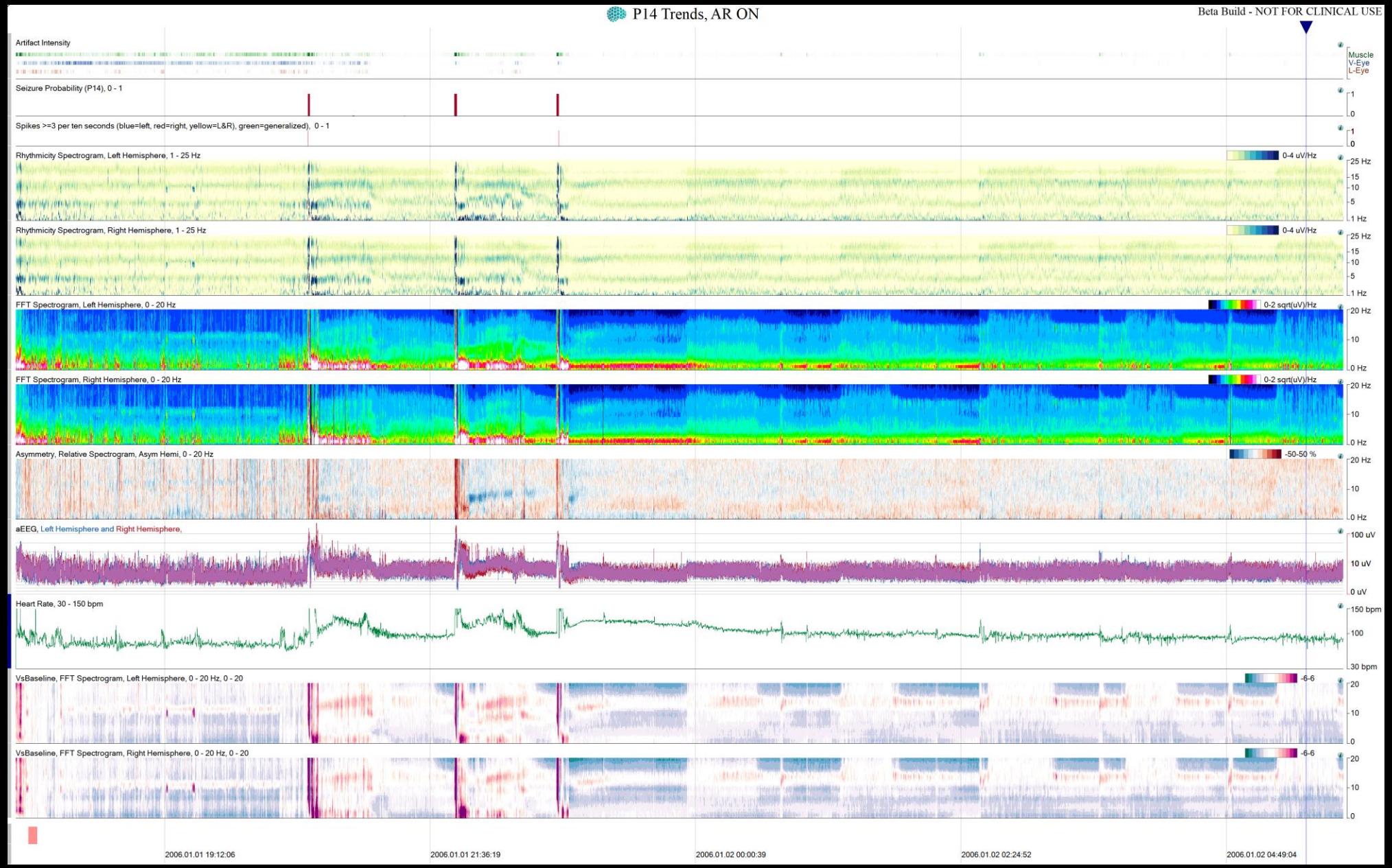




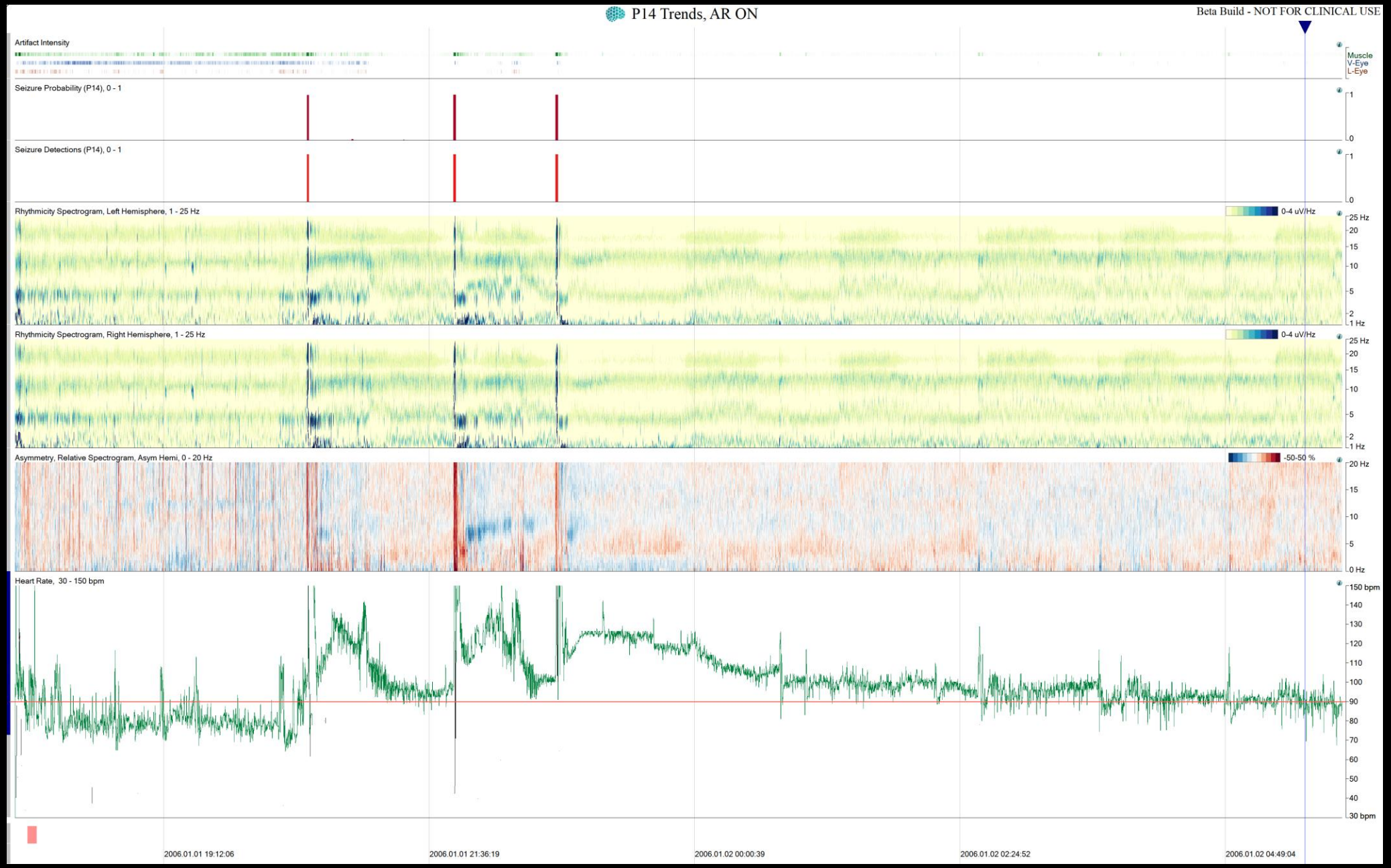
Same image, now with Artifact Reduction engaged to allow better visualization of cerebral activity in EEG



12-hour view: 3 seizures evident; seizures stopped after iv lorazepam bolus (note heart rate trend)



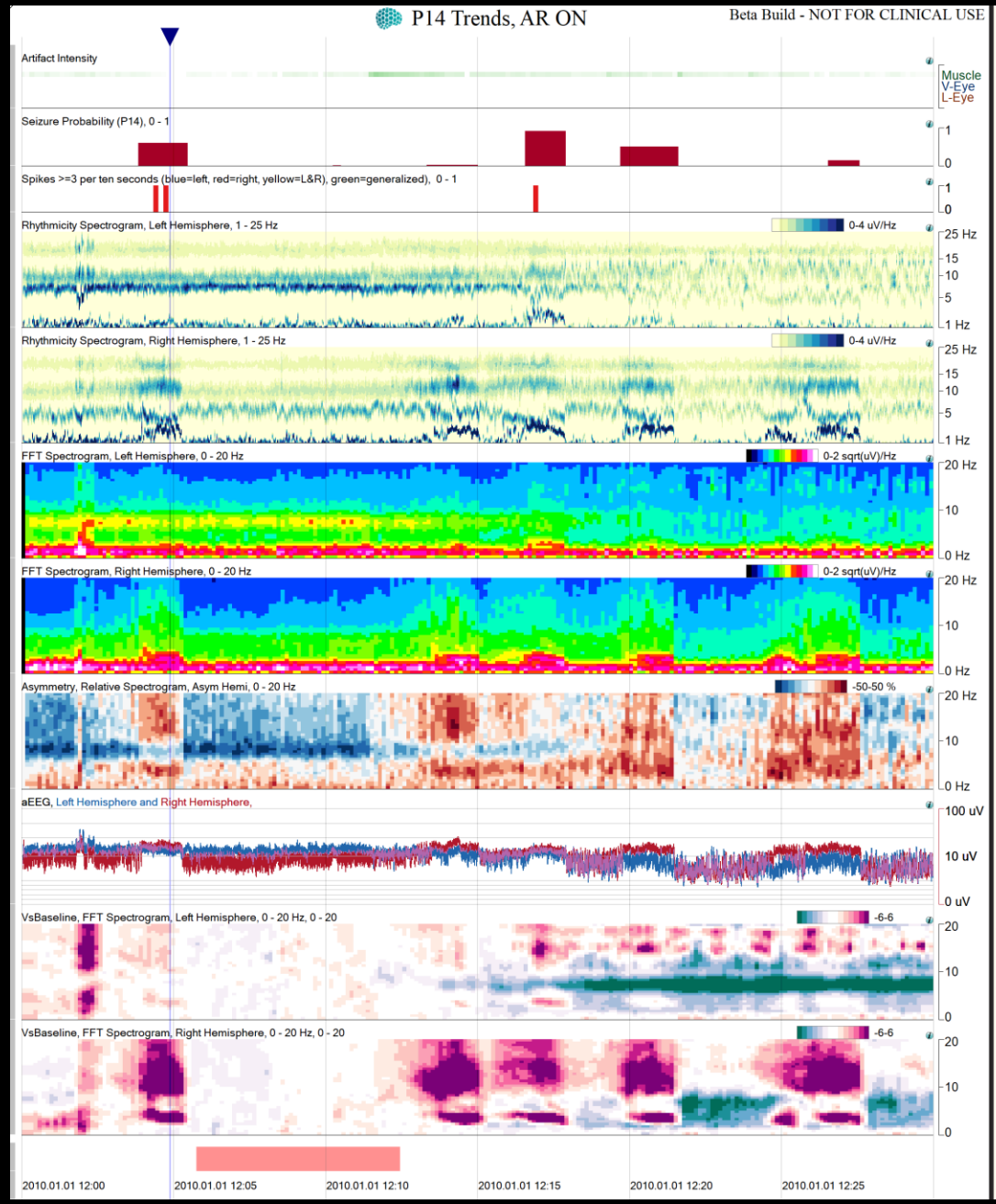
12-hour view: Progressive post-ictal tachycardia



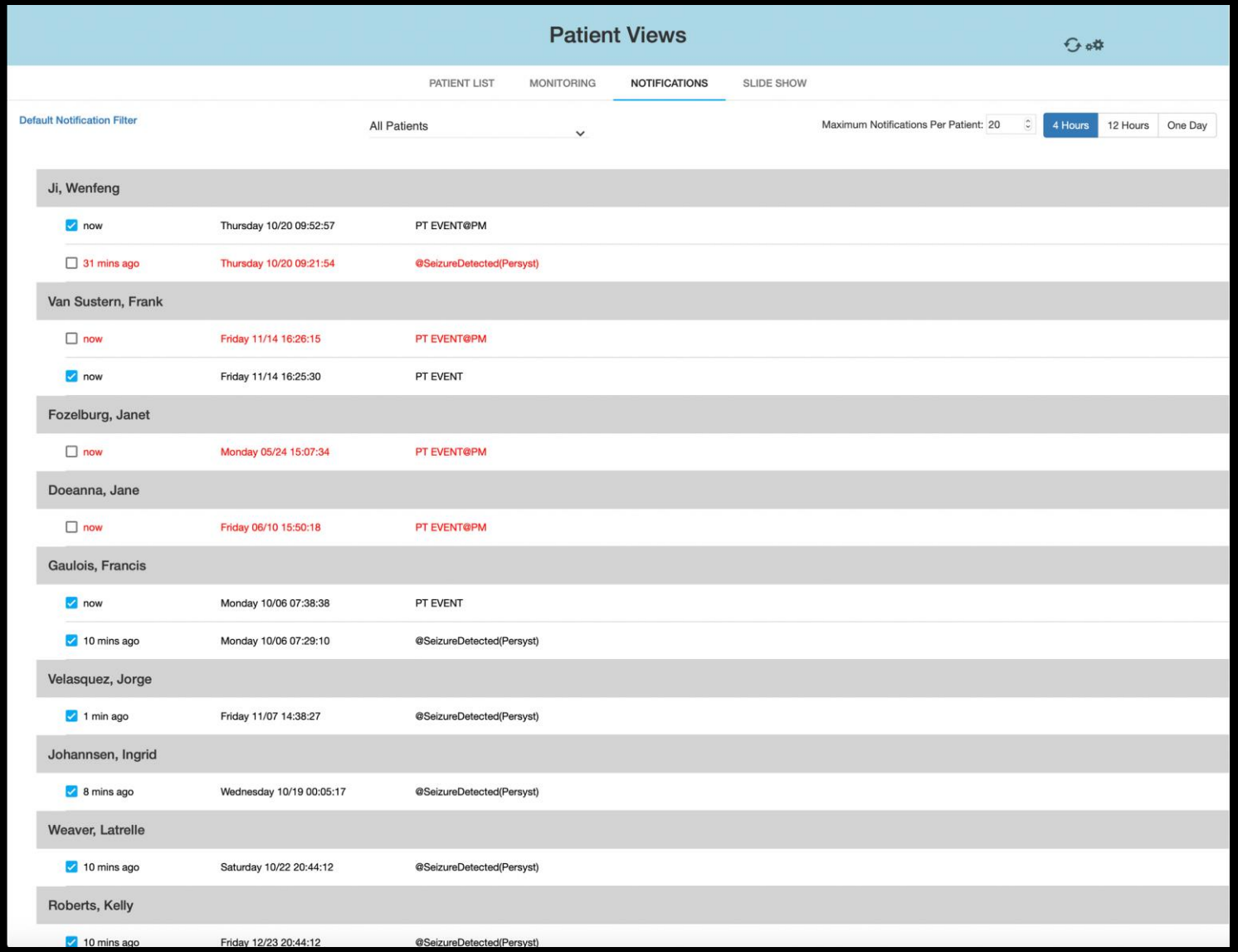
Case 5: Sonya Winters

- ~60 y/o
- Prior stroke, episodes left arm shaking and slurred speech
- Right SDH on imaging
- Admitted to ICU, initially treated with levetiracetam iv, somnolent
- cEEG to assess for possible seizures and effectiveness of treatment

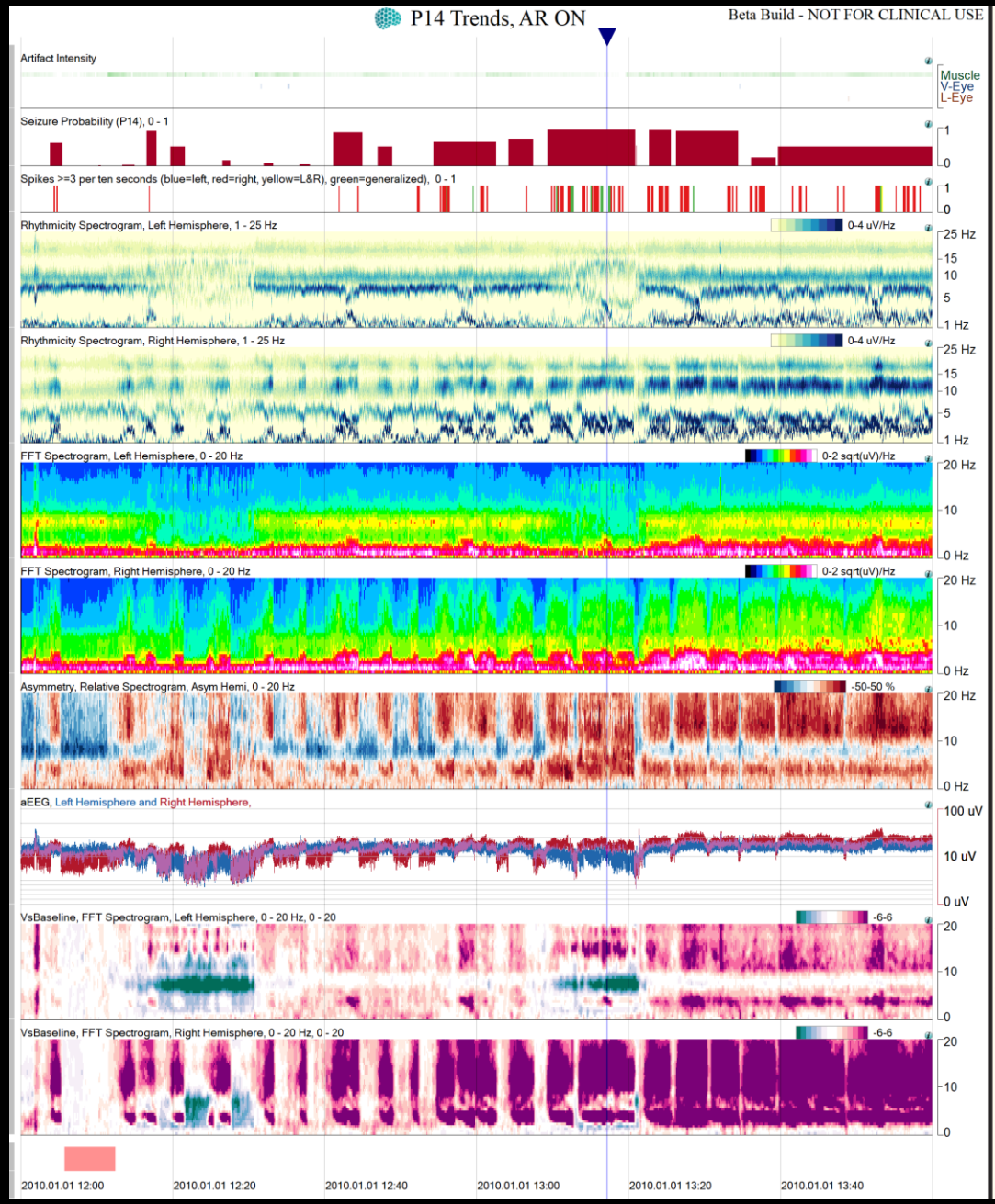
First 30-minutes of recording: multiple seizures detected; notifications sent

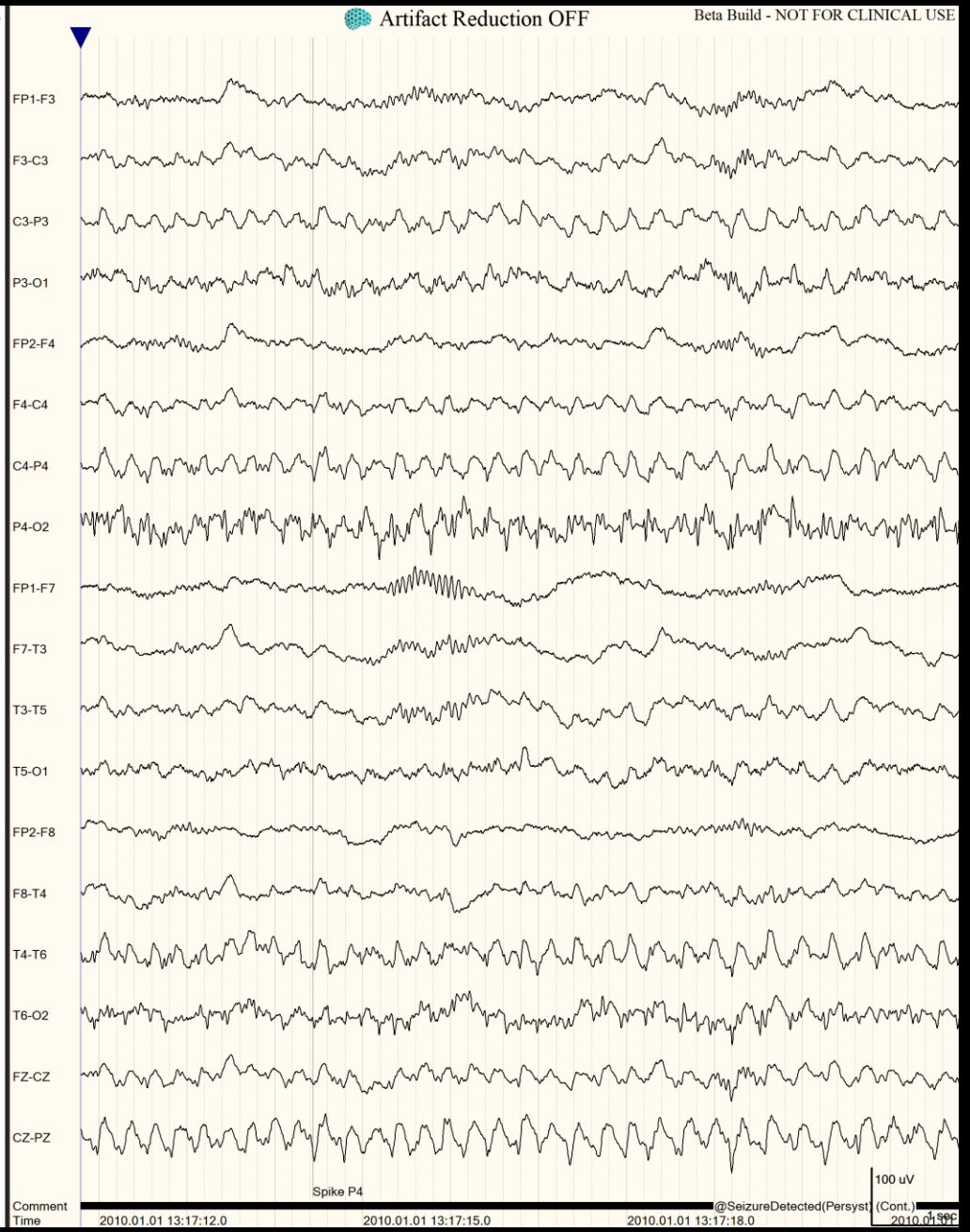


Mobile Monitoring using iPad/iPhone or web app (2019): Remote notification

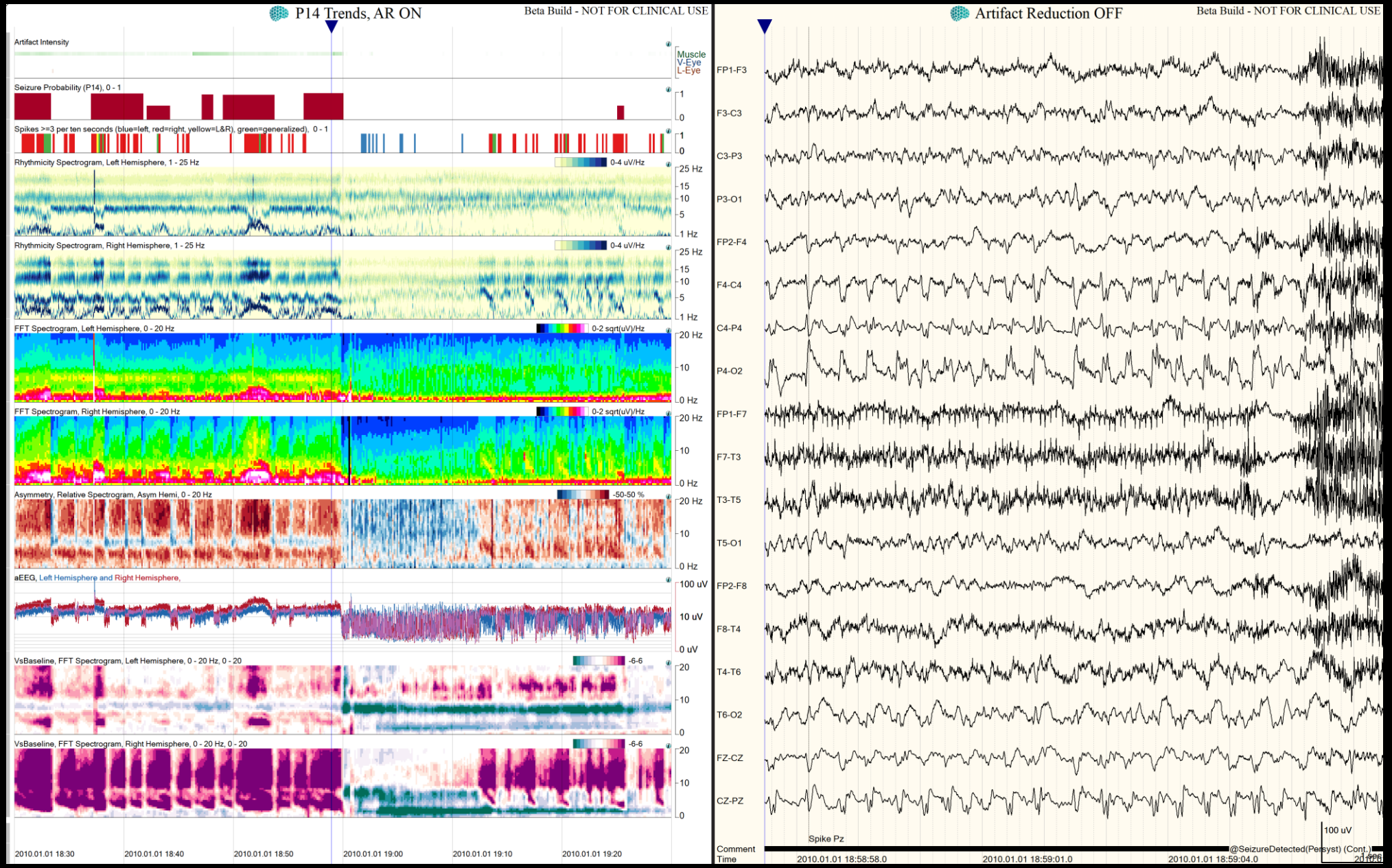


Initial 2-hours monitoring: trends c/w status epilepticus; no significant effect from therapy





Several hours later: note marked EEG change mid-way through this one-hour segment
What happened?



Intubation using etomidate (arrow); 1-hour view; seizures soon recur but with altered signature