

SLEEP STAGING AND AROUSAL

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Scoring of Sleep Stages in Adults

A. Stages of Sleep –

- Stage W
- Stage N1
- Stage N2
- Stage N3
- Stage R

B. Scoring by Epochs –

- Score sleep stages in 30 second sequential epochs commencing at the start of the study
- Assign a stage to each epoch
- If 2 or more stages coexist during a single epoch, assign the stage comprising the greatest portion of the epoch

Stage W

Definitions:

Alpha Rhythm –

- Trains of sinusoidal 8-13 Hz activity recorded over the occipital region with eye closure, attenuating with eye opening.

Eye Blinks –

- Conjugate vertical eye movements at a frequency of 0.5-2 Hz present in wakefulness with the eyes open or closed.

Reading Eye Movements –

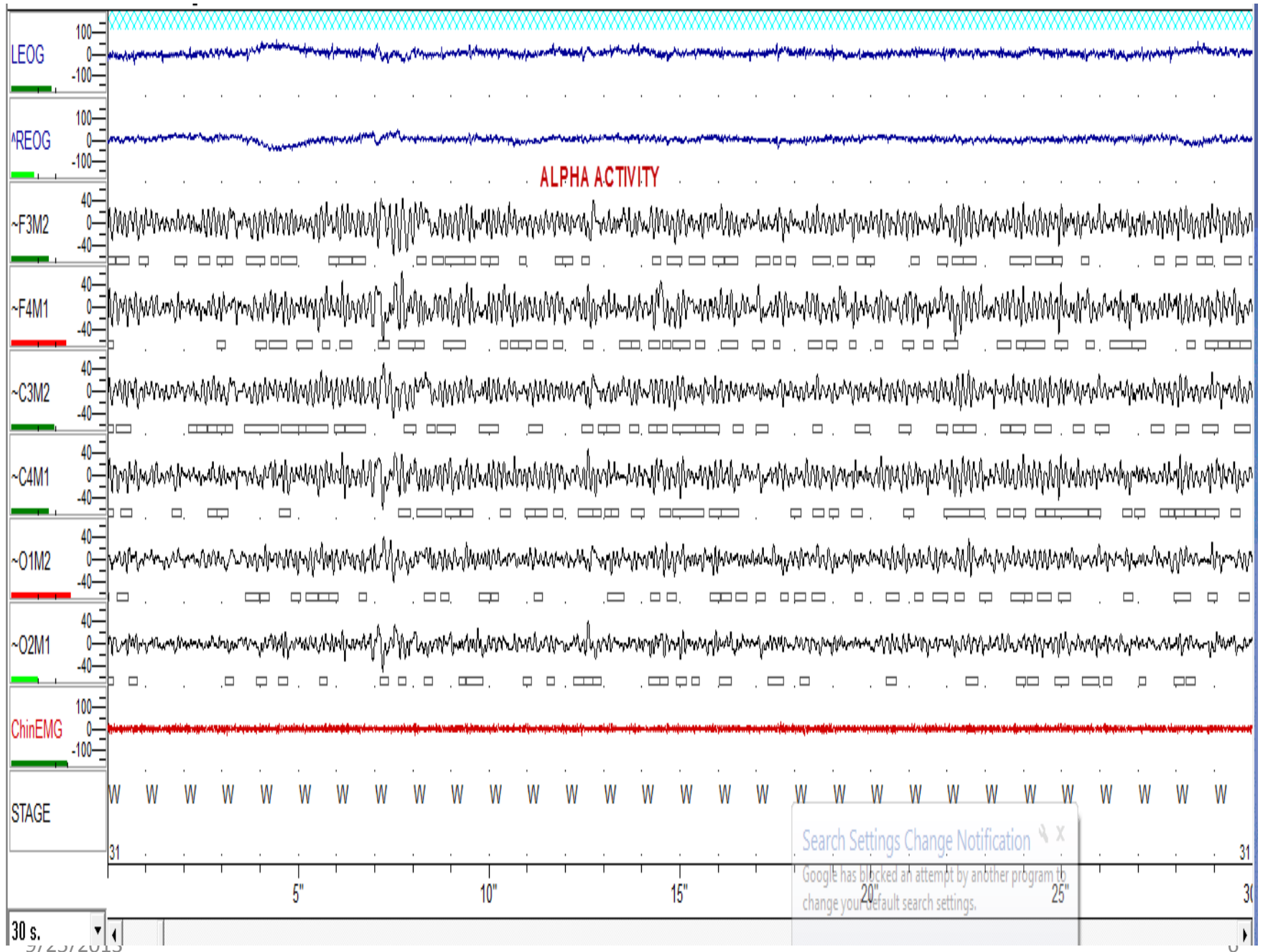
- Trains of conjugate eye movements consisting of a slow phase followed by a rapid phase in the opposite direction as the subjects reads.

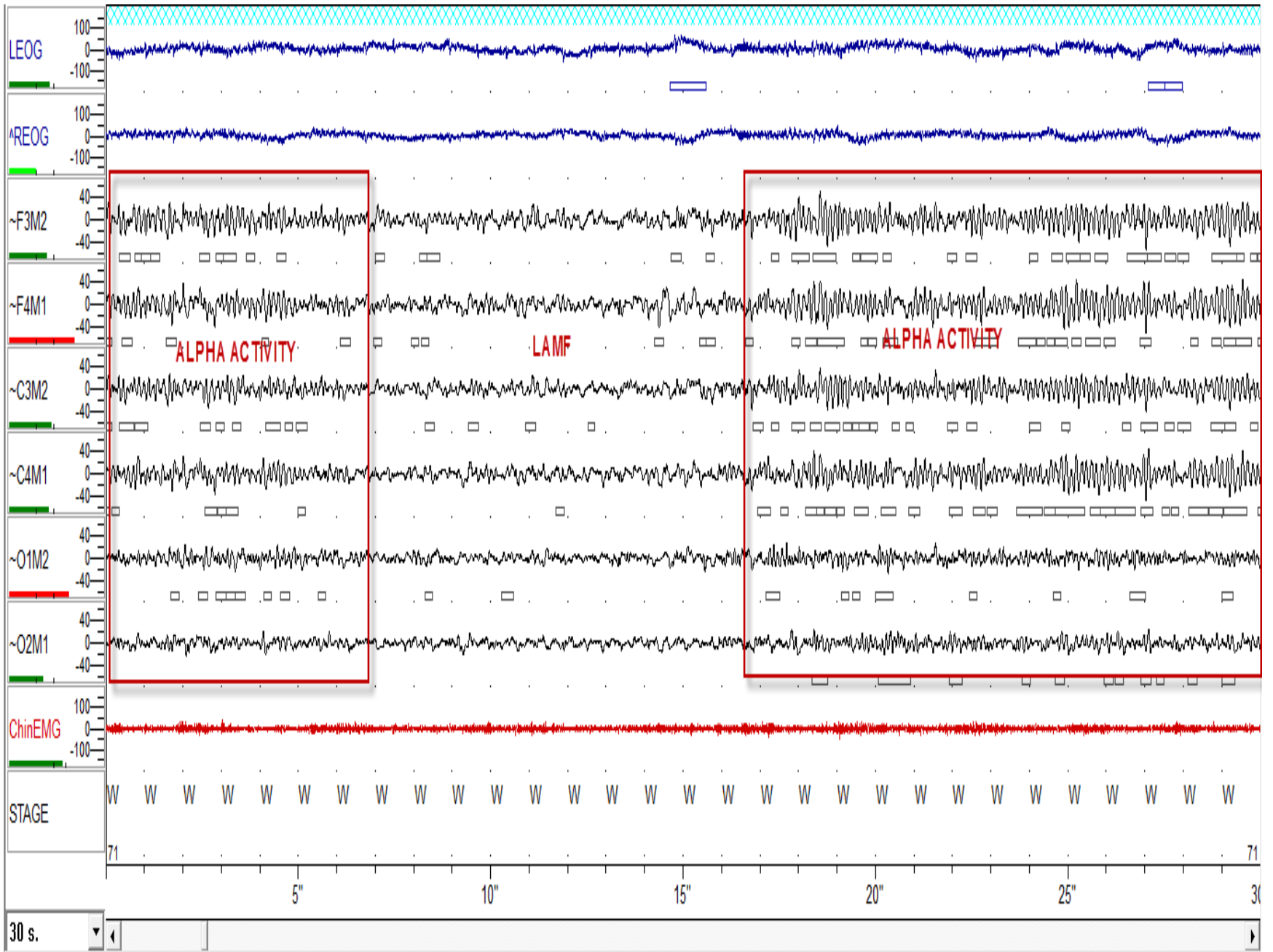
Rapid Eye Movements (REM) –

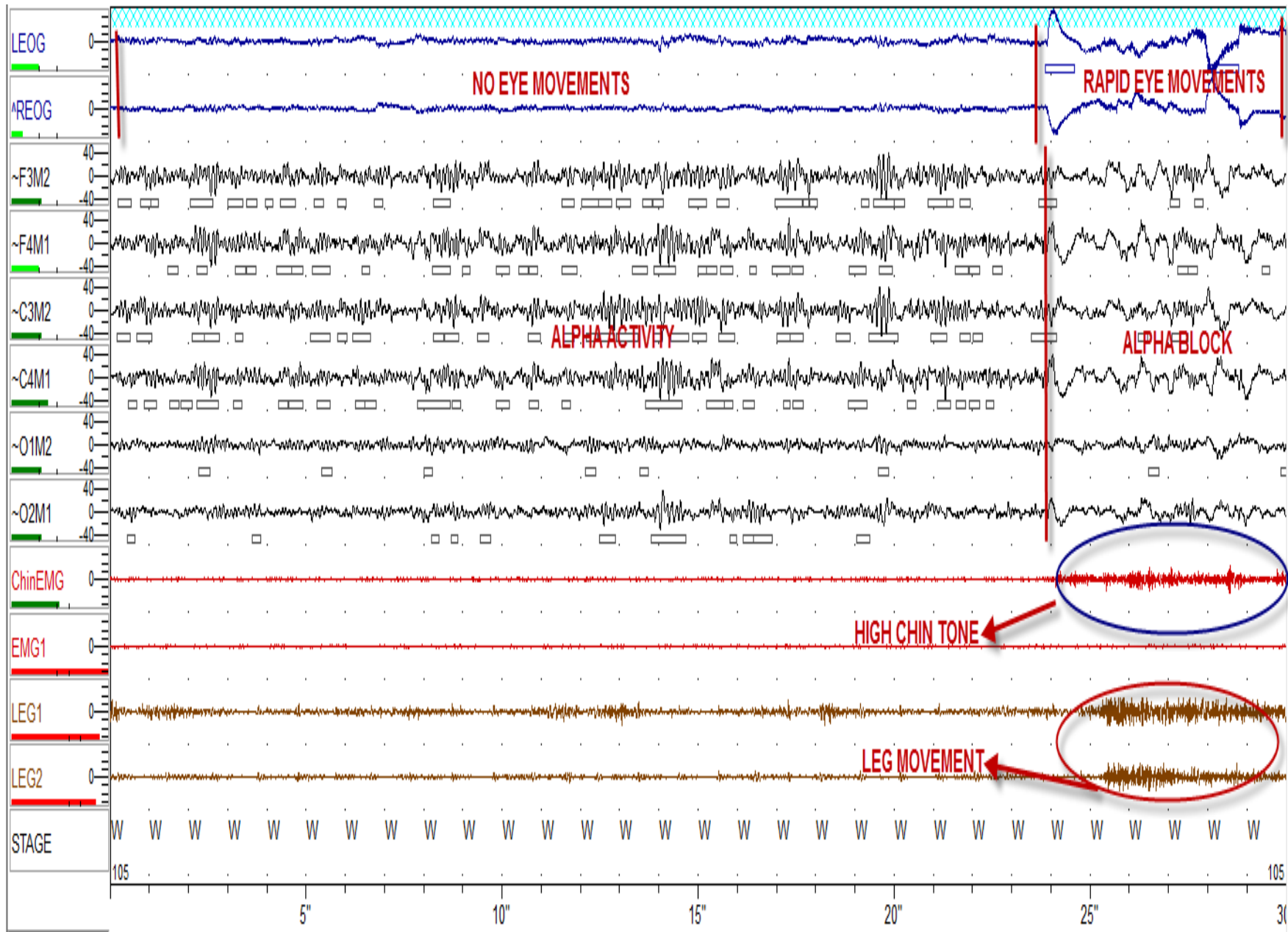
- Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500 msec. While rapid eye movements are characteristic of stage R sleep, they may also be seen in wakefulness with eyes open when subjects scan the environment

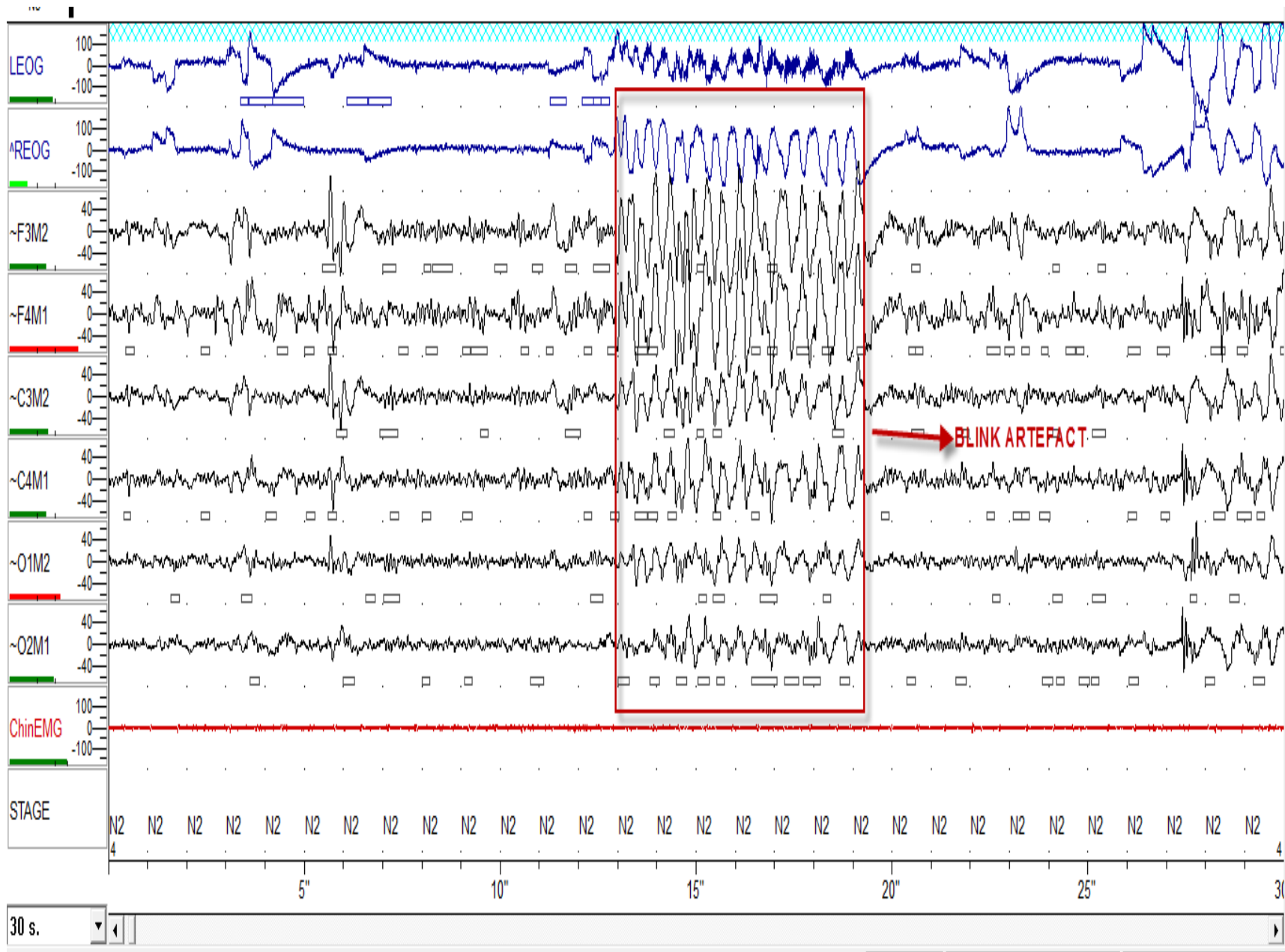
Rules –

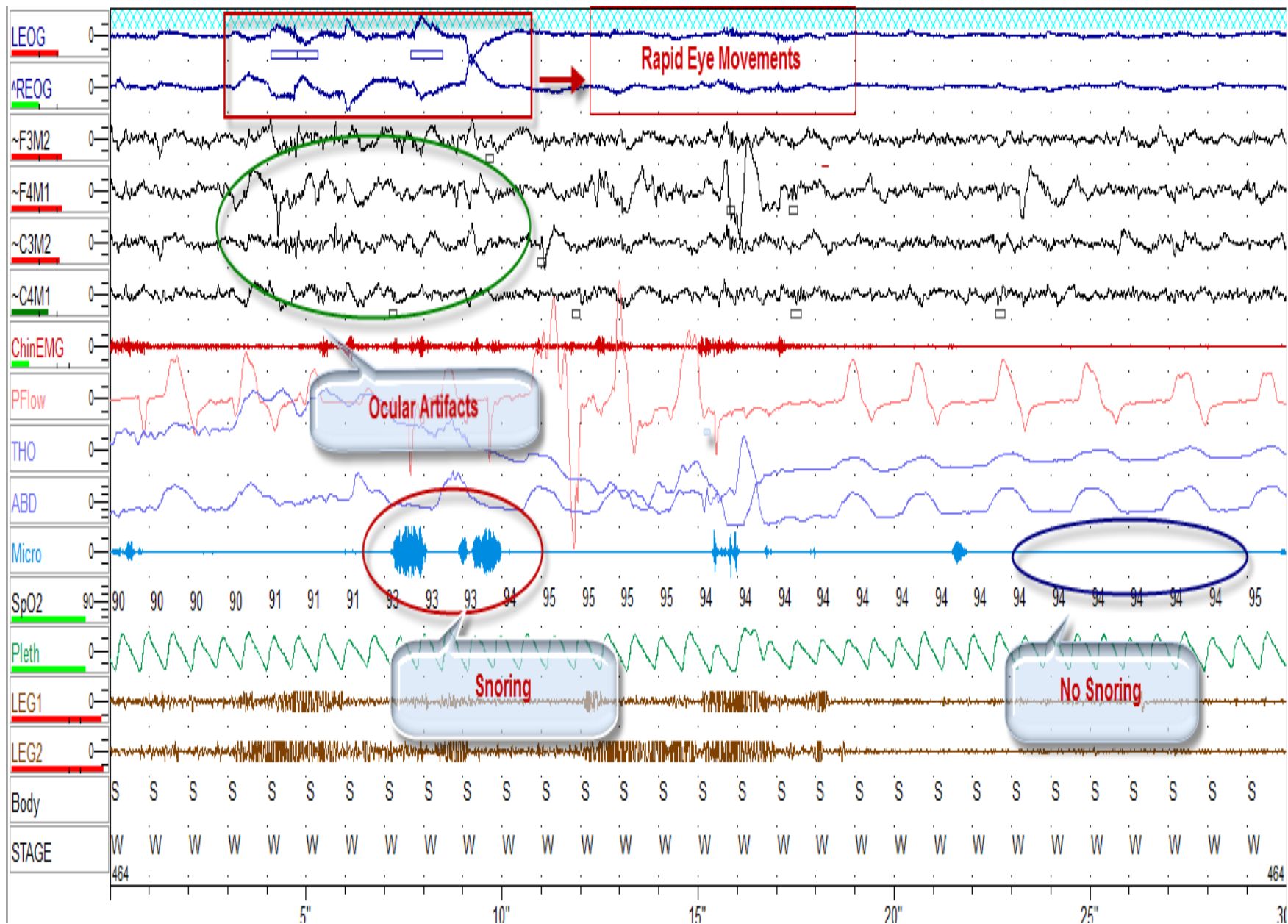
- Score epochs as stage W when more than 50% of the epoch has alpha rhythm over the occipital region.
- Score epochs without visually discernable alpha rhythm as stage w if any of the following are present –
 - ❑ Eye blinks at a frequency of 0.5-2 Hz
 - ❑ Reading eye movements
 - ❑ Irregular conjugate rapid eye movements associated with normal or high chin muscle tone.











Sleep Onset –

- The start of the first epoch scored as any stage other than stage W. (In most subjects this will usually be the first epoch of stage N1)

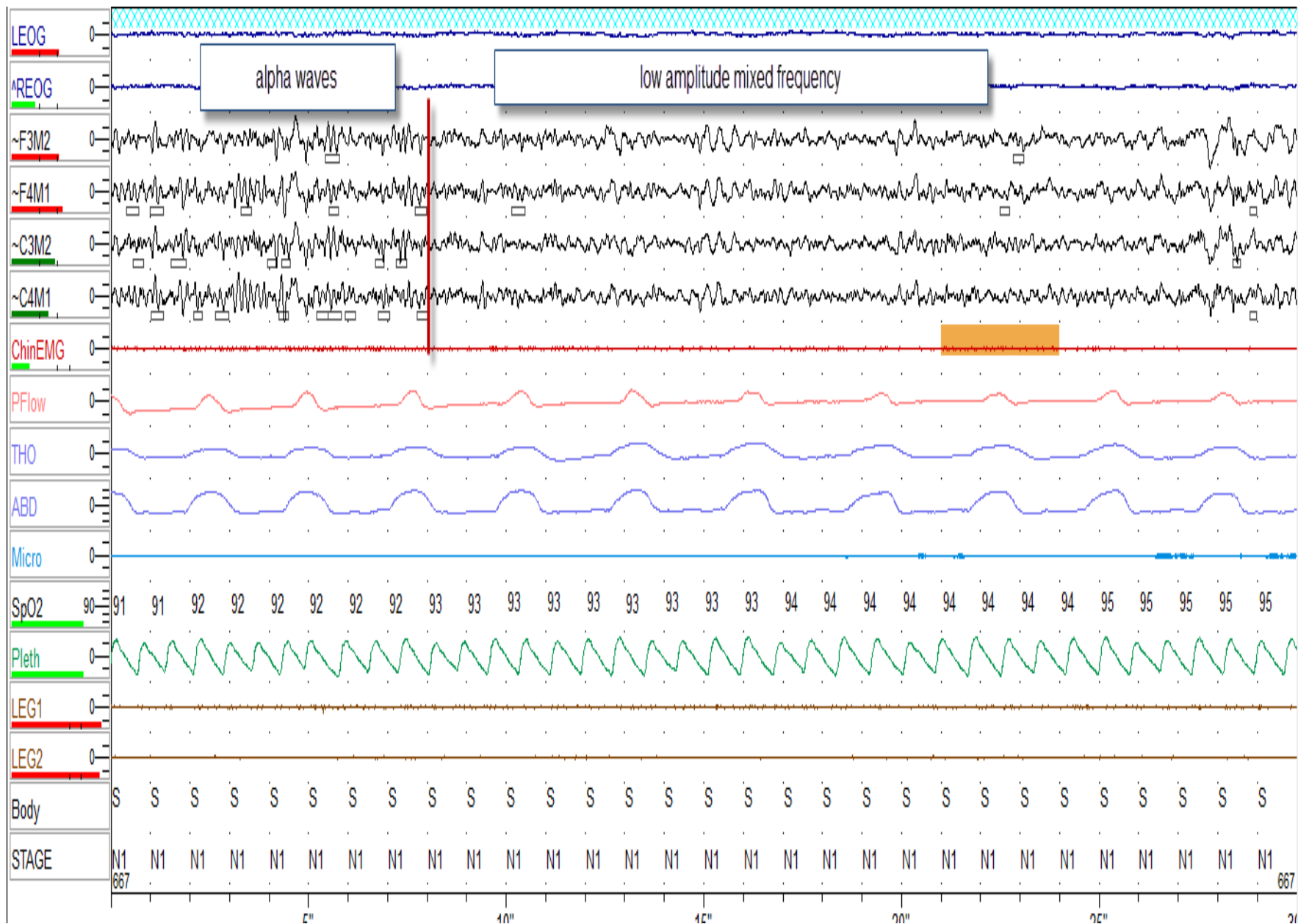
Stage N1

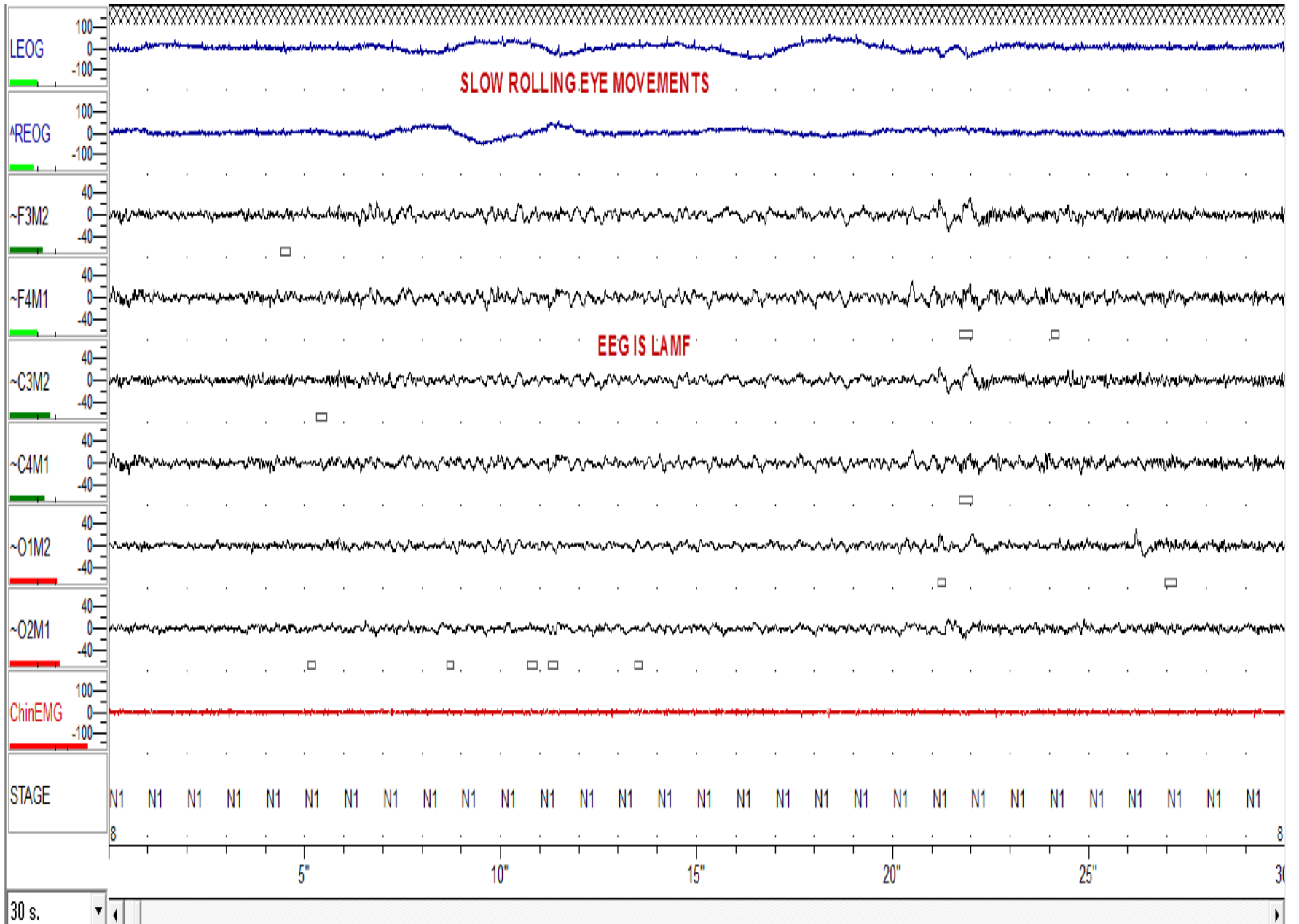
Definitions –

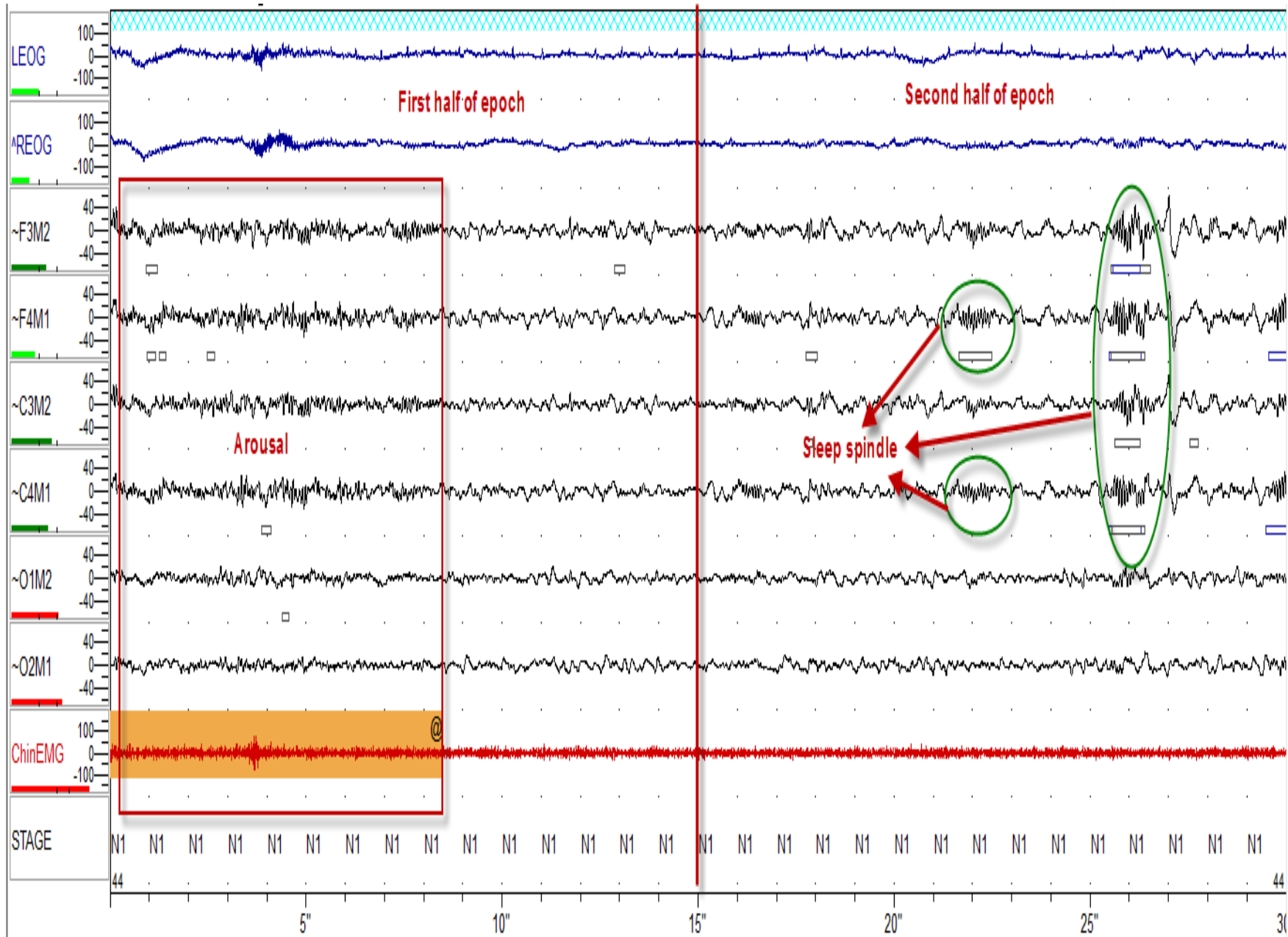
- **Slow Eye Movements (SEM)** - Conjugate, reasonably regular, sinusoidal eye movements with an initial deflection usually lasting >500 msec
- **Low amplitude, mixed frequency activity** - Low amplitude, predominantly 4-7 Hz activity
- **Vertex sharp waves (V waves)** - Sharply contoured waves with duration <0.5 seconds maximal over the central region and distinguishable from the background activity

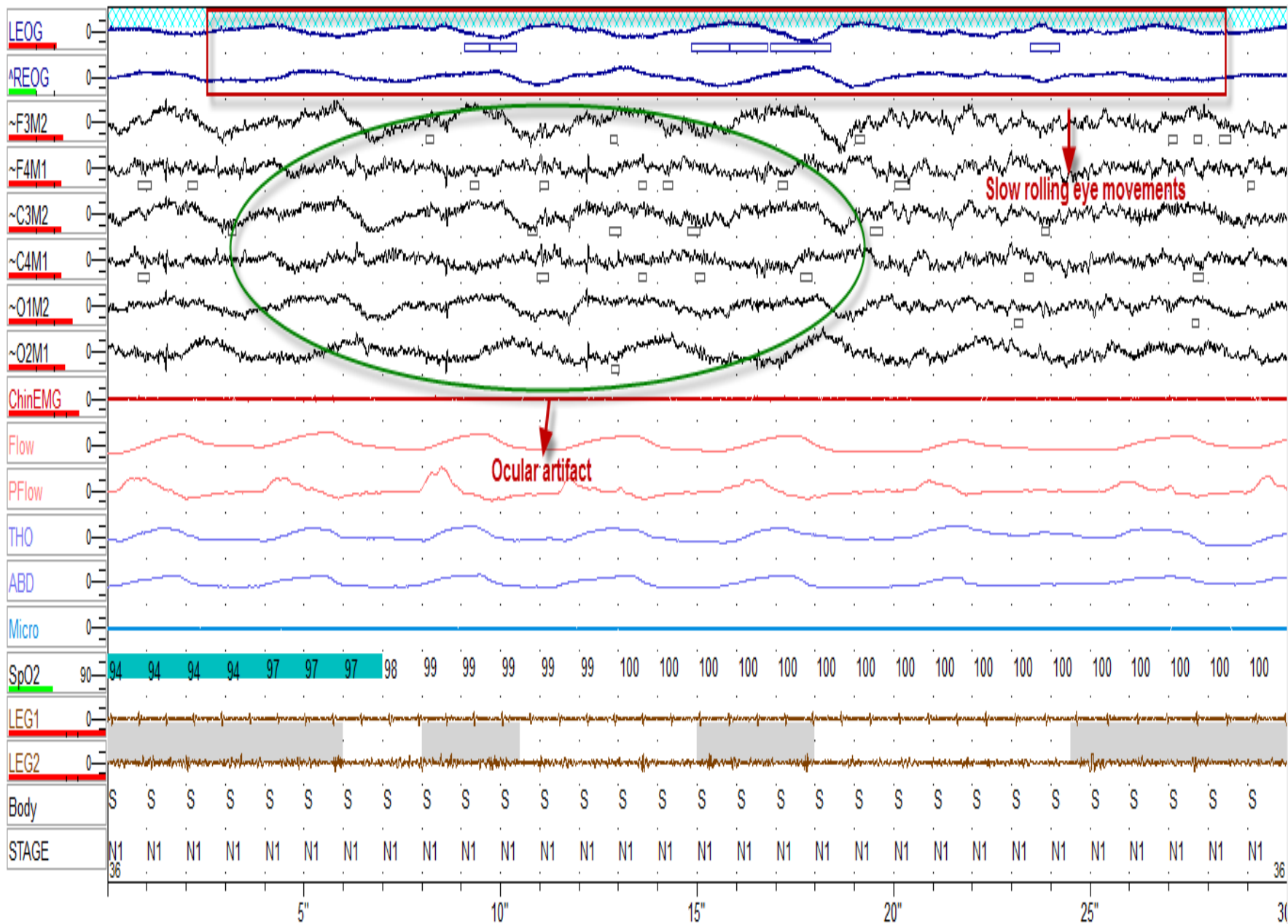
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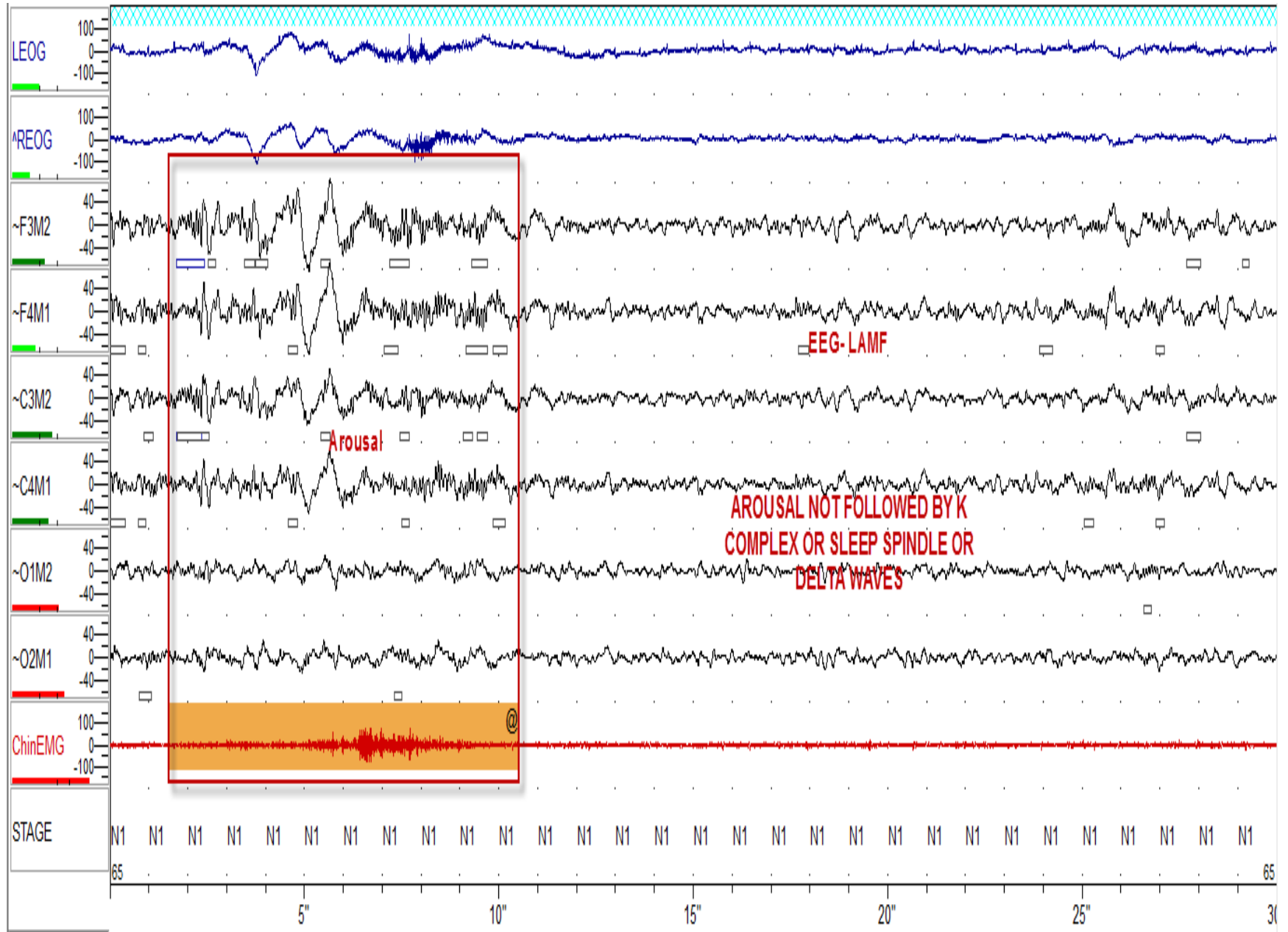
- In subjects who generate alpha rhythm, score stage N1 if alpha rhythm is attenuated and replaced by low amplitude, mixed frequency activity for more than 50% of the epoch.
- In subjects who do not generate alpha rhythm, score stage N1 commencing with the earliest of any of the following phenomena.
 - Activity in range of 4-7 Hz with slowing of background frequencies by ≥ 1 Hz from those of stage W.
 - Vertex sharp waves.
 - Slow eye movements







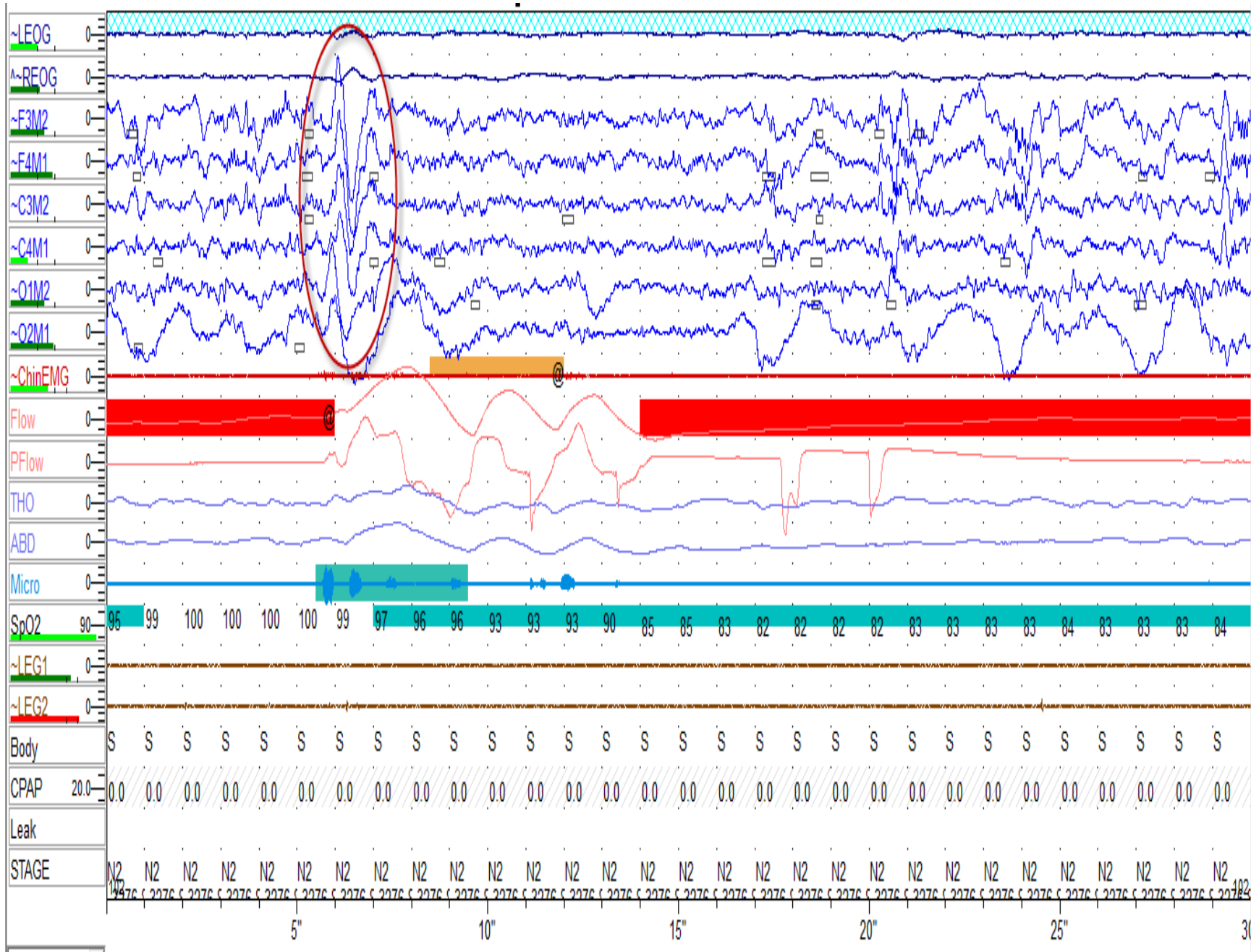




Stage N2

Definitions –

- **K Complex** - A well-delineated negative sharp wave immediately followed by a positive component standing out from the background EEG, with total duration ≥ 0.5 seconds, usually maximal in amplitude when recorded using frontal derivations. For an arousal to be associated with K complex, it must commence no more than 1 second after termination of the K complex.

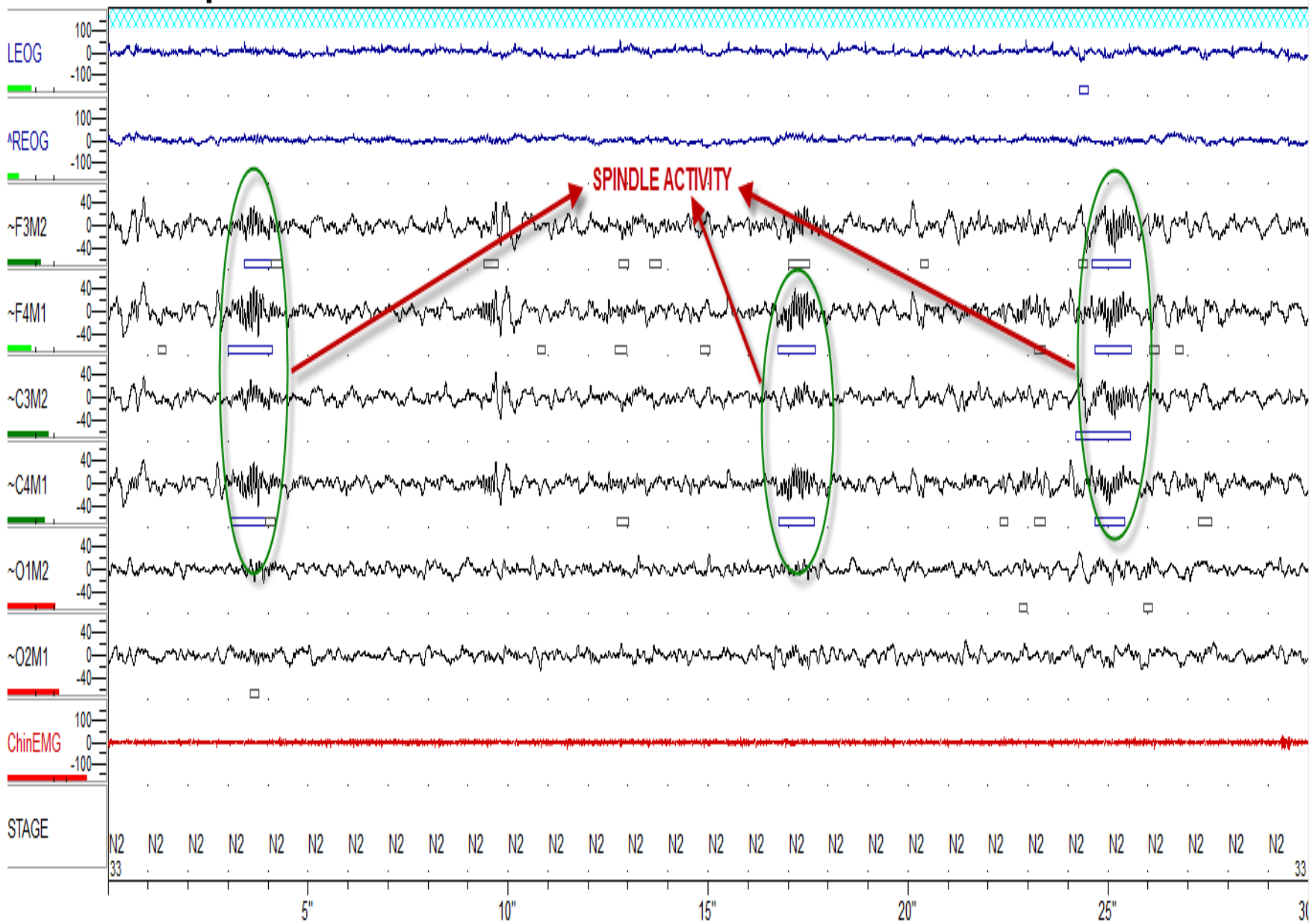


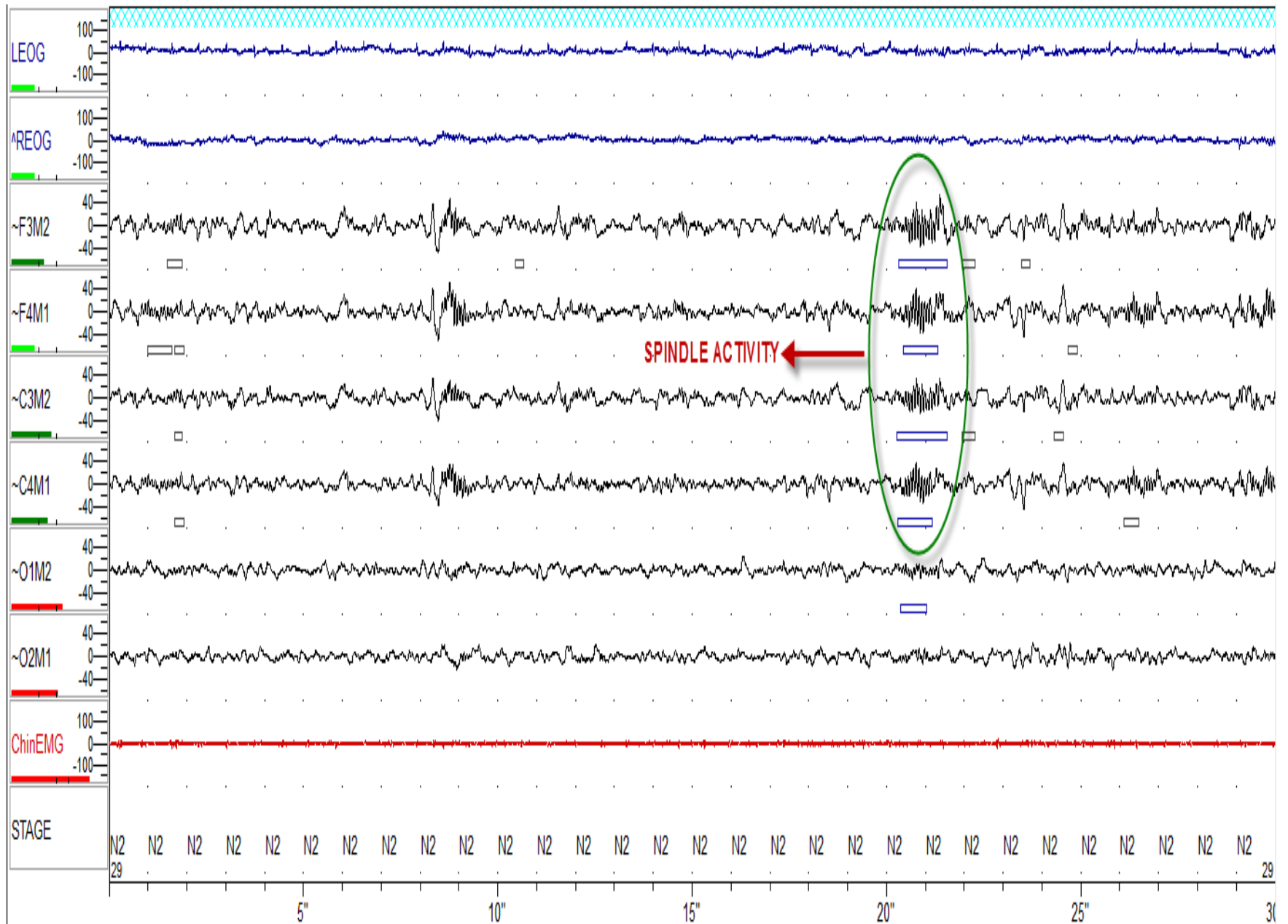
- **Sleep Spindle:** A train of distinct waves with frequency 11-16 Hz (most commonly 12-14 Hz) with a duration ≥ 0.5 seconds, usually maximal in amplitude using central derivations

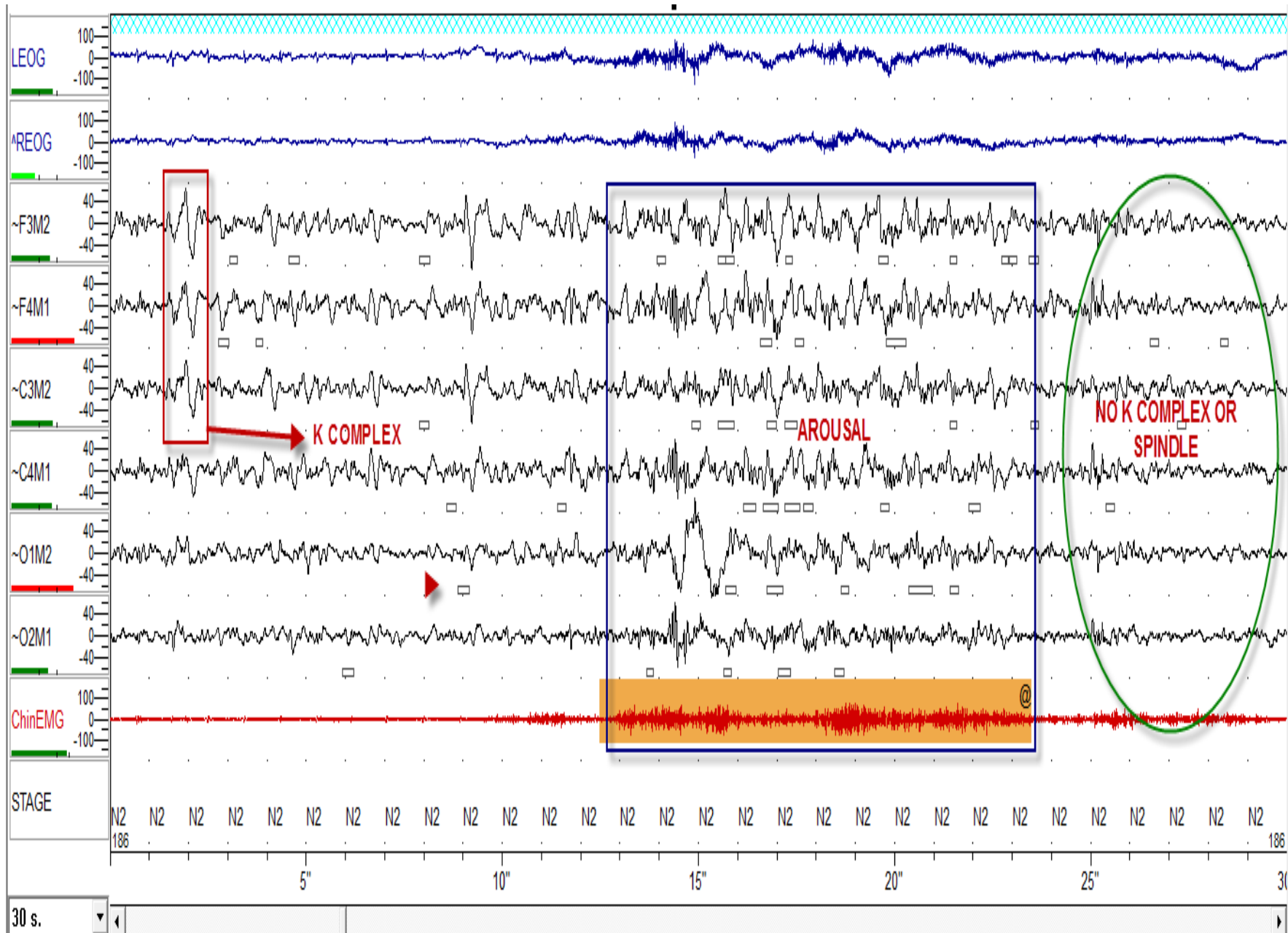
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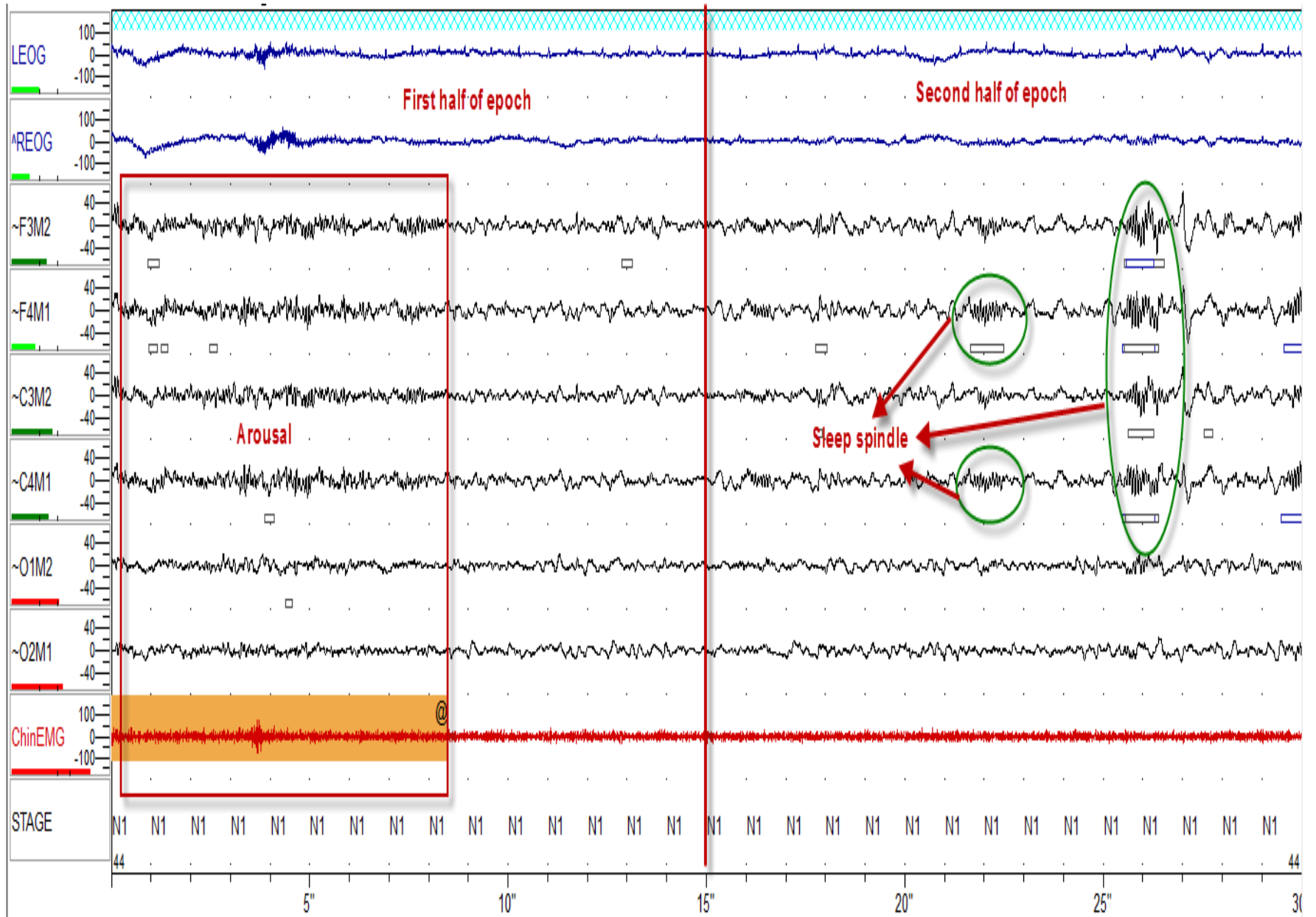
A. The following rule defines the start of a period of stage N2 sleep –

- Begin scoring stage N2 (in absence of criteria for N3) if 1 or both of the following occur during the first half of that epoch or the last of the previous epoch:
 - ❑ One or more K complexes unassociated with arousals
 - ❑ One or more trains of sleep spindles









Note –

- Continue to score stage N1 for epoch with arousals-associated K complexes but no spontaneous K complexes or sleep spindles
- For the purposes of scoring N2 sleep, arousals are defined according to arousal rule

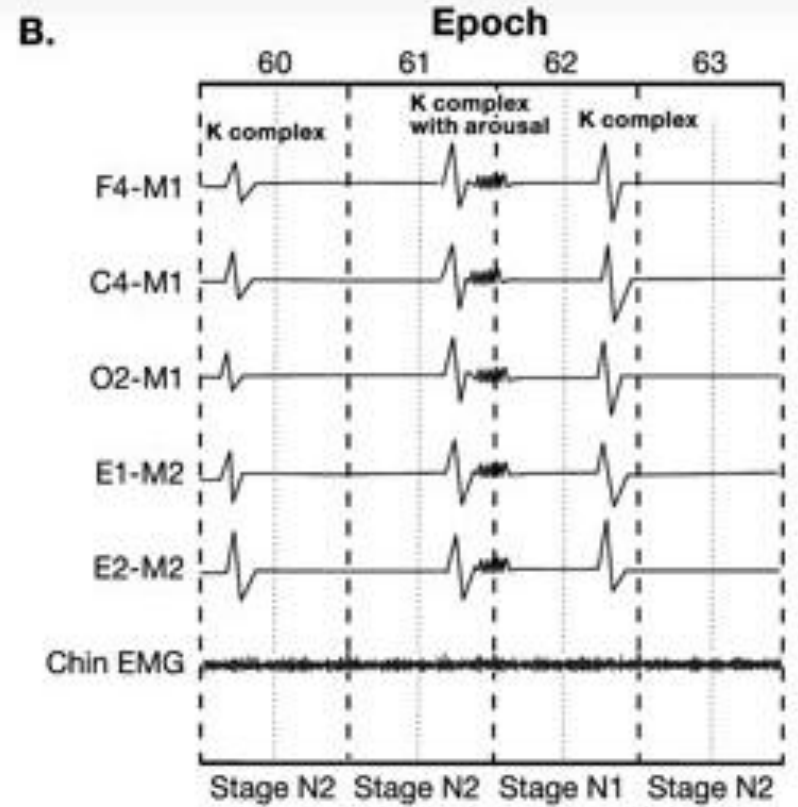
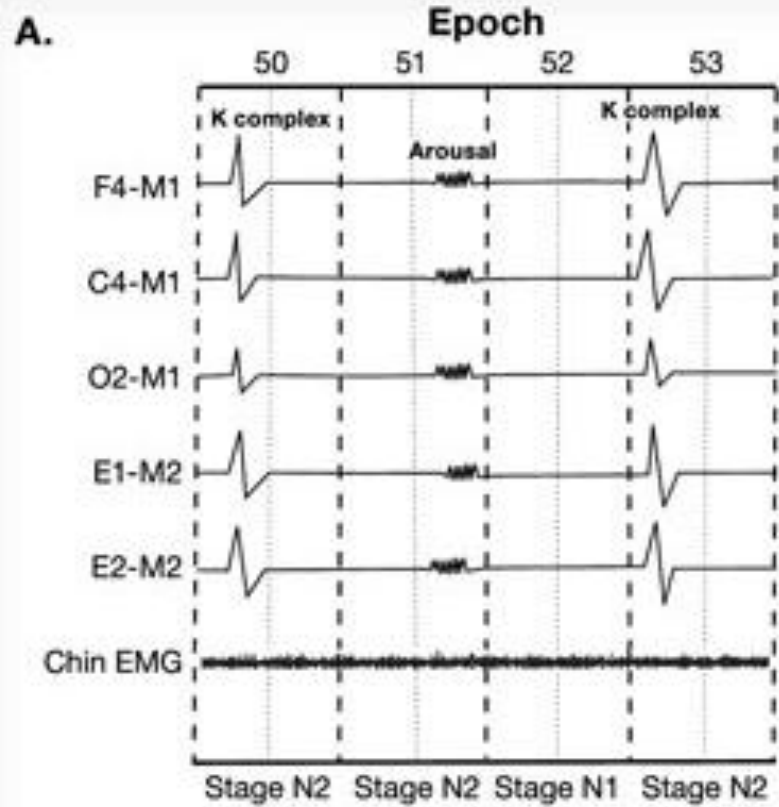
B. The following rule defines continuation of a period of stage N2 sleep :

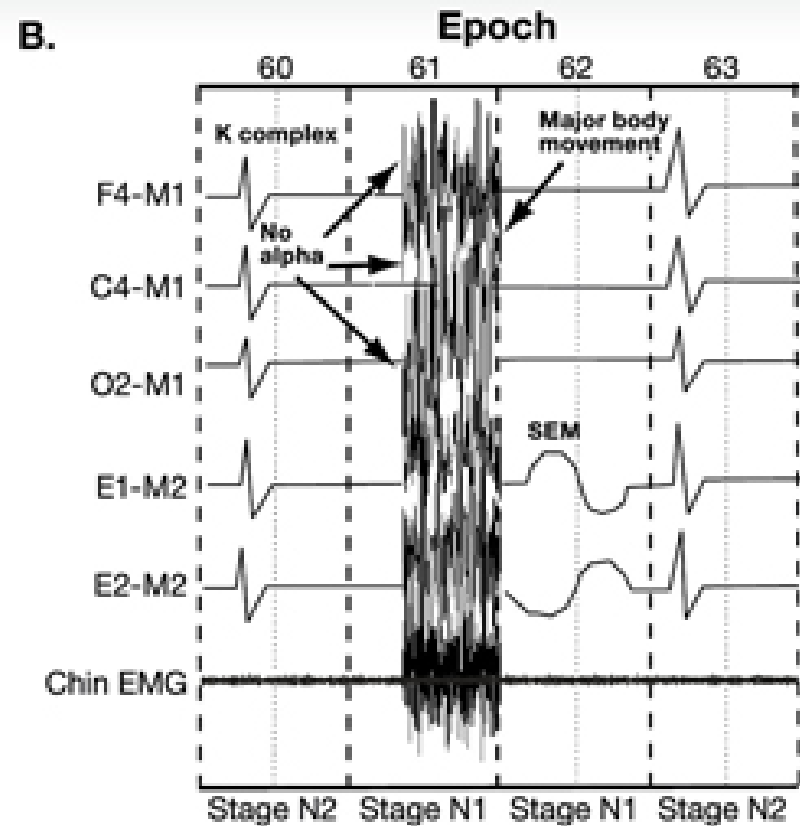
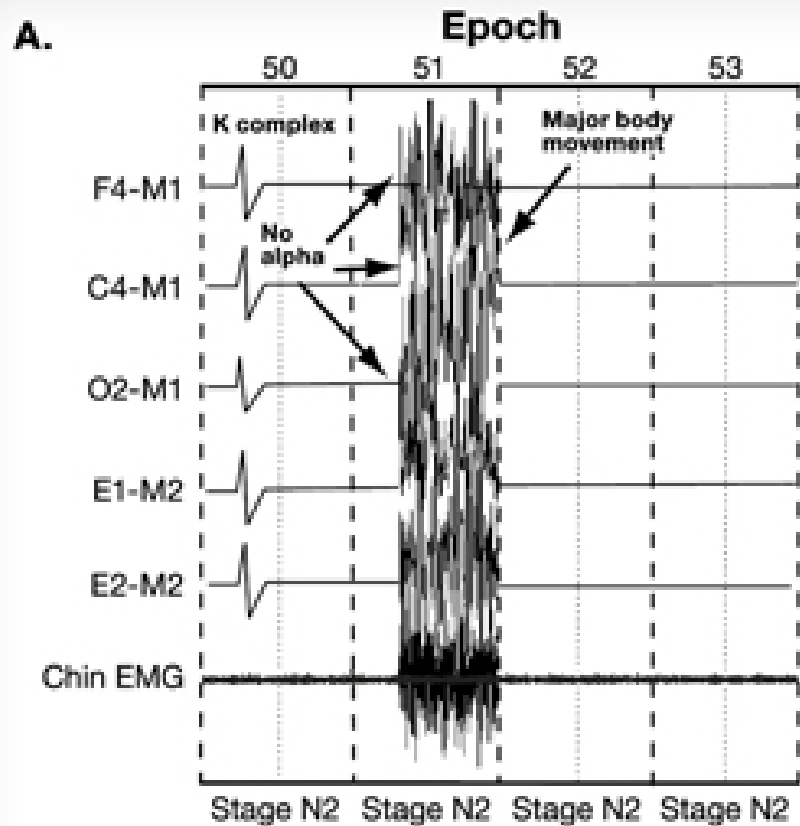
- Continue to score epochs with low amplitude, mixed frequency EEG activity without K complexes or sleep spindles as stage N2 if they are preceded by a) K complexes unassociated with arousals or b) sleep spindles.

C. The following rule defines the end of a period of stage N2 sleep :

- End stage N2 sleep when 1 of the following events occurs:
 - Transition to stage W

- ❑ An arousal (change to stage N1 until a K complex unassociated with an arousal or a sleep spindle occurs)
- ❑ A major body movement followed by slow eye movements and low amplitude mixed frequency EEG without non arousal associated K complexes or sleep spindles (score the epoch following the major body movements as stage N1; score the epoch as stage N2 if there are no slow eye movements; the epoch containing the body movements is scored using movement criteria)
- ❑ Transition to stage N3
- ❑ Transition to stage R





Notes –

- The EOG usually shows no eye movements activity during stage N2 sleep, but slow eye movements may persist in some subjects.
- In stage N2 the chin EMG is of variable amplitude, but is usually lower than in stage W, and may be as in stage R sleep.
- Although sleep spindles and frequency changes associated with arousals are more typically noted in the central and occipital derivations respectively, these events should be used to score sleep even if they are only noted in the frontal derivations.

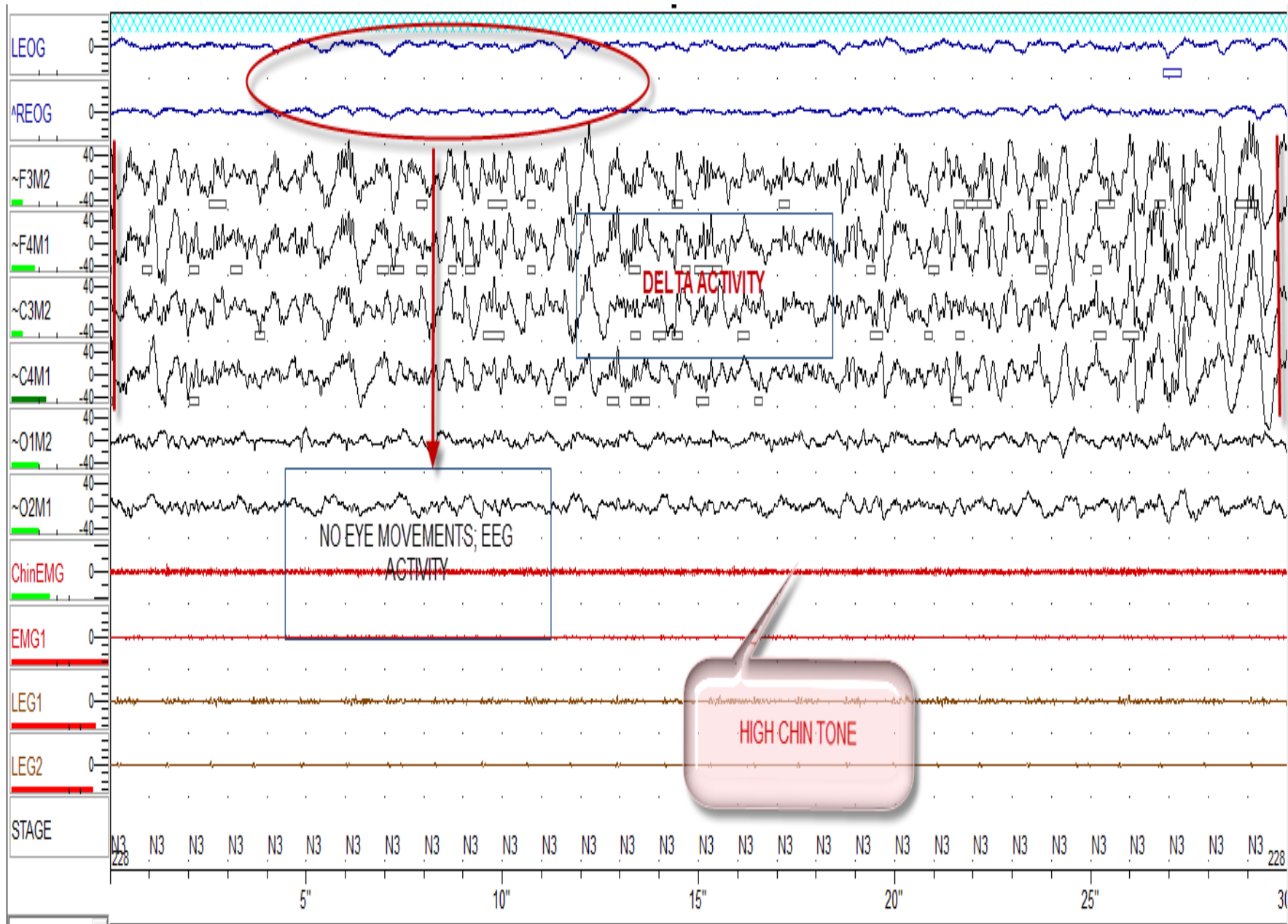
Stage N3

Definition

- Slow wave activity: waves of frequency 0.5Hz-2 Hz and peak amplitude $>75\mu\text{V}$, measured over the frontal regions.

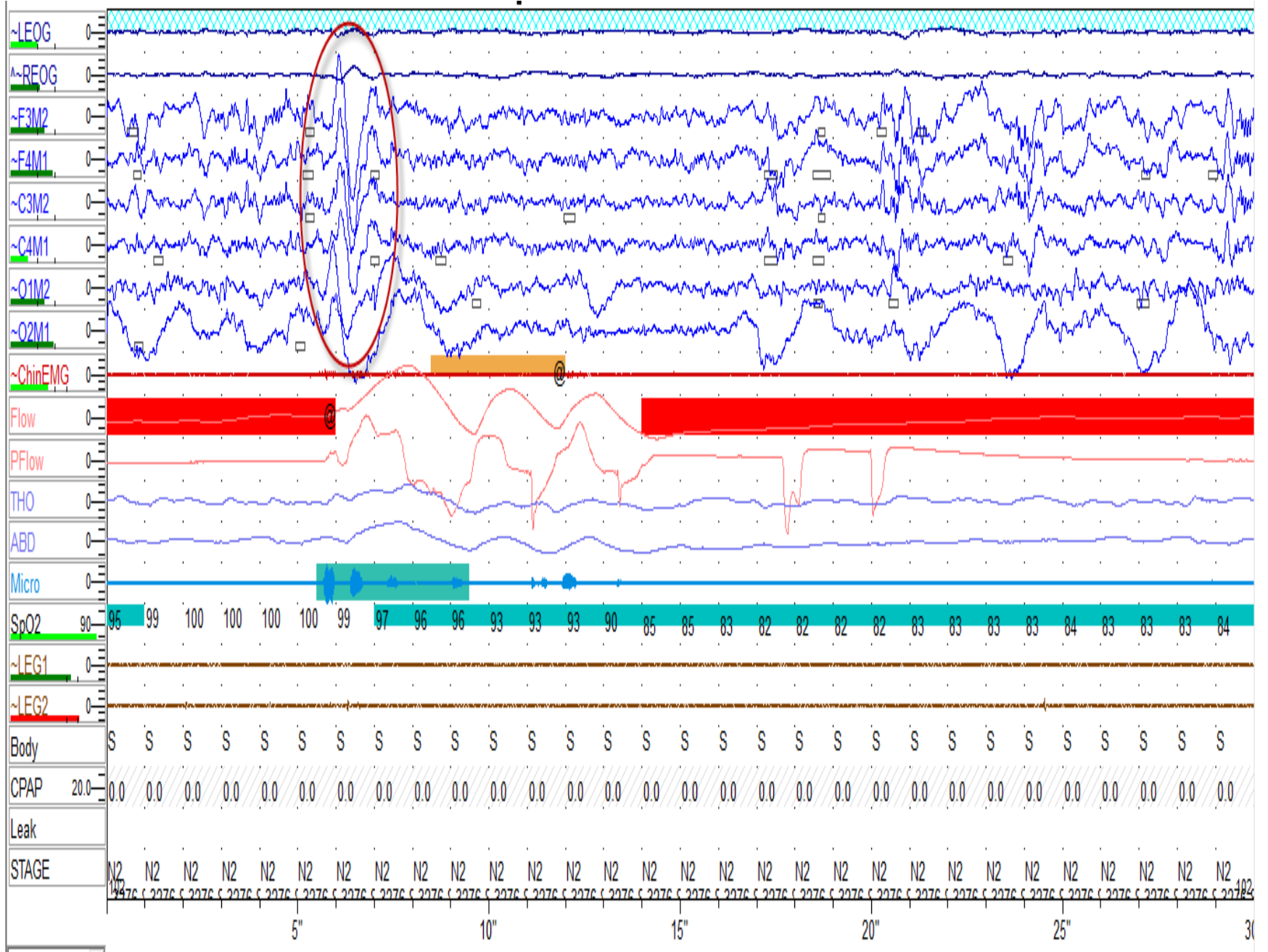
Rules –

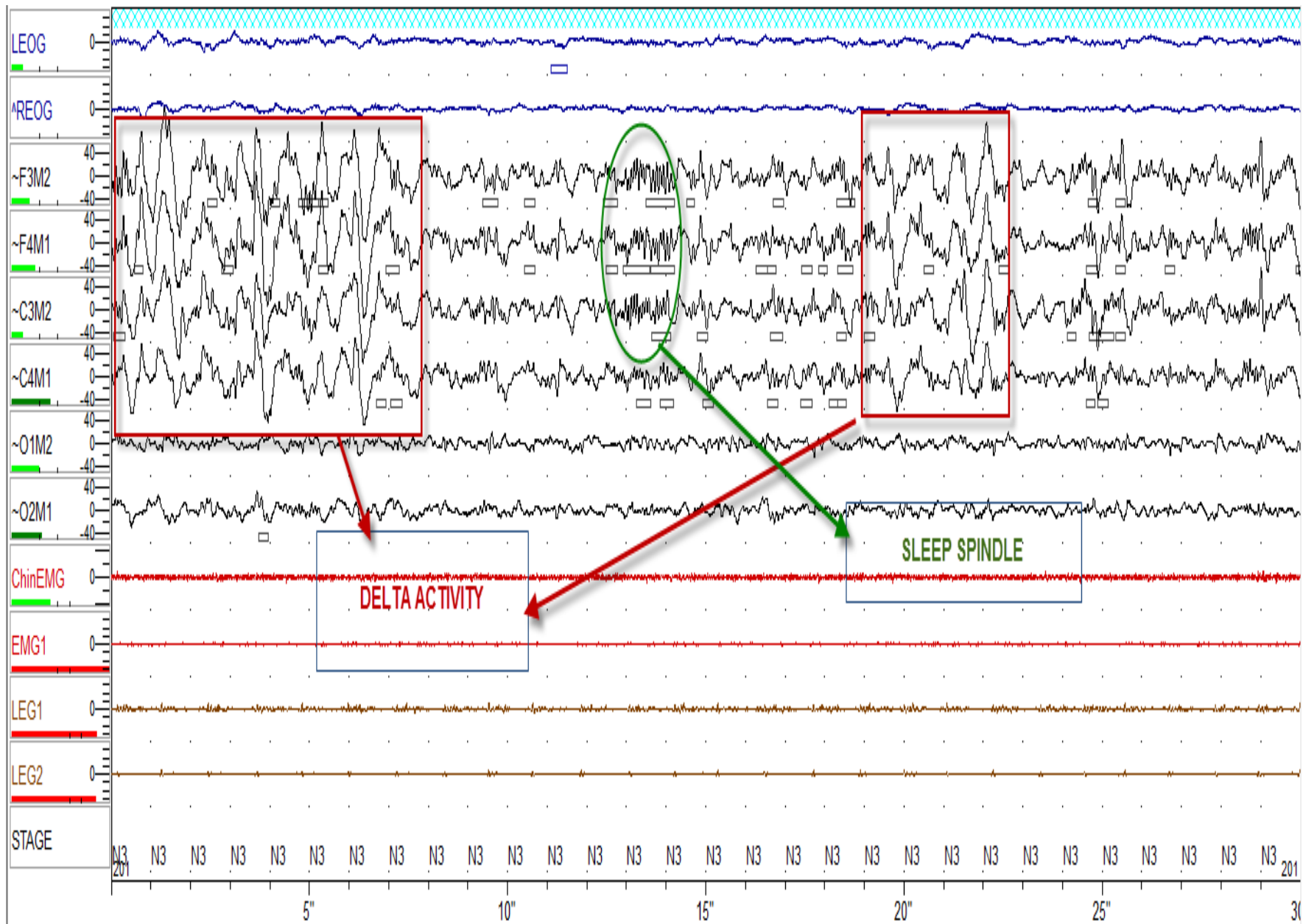
- Score stage N3 when 20% or more of an epoch consists of slow wave activity, irrespective of age.



Notes –

- Sleep spindles may persist in stage N3 sleep
- Eye movements are not typically seen during stage N3 sleep
- In stage N3, the chin EMG is of variable amplitude, often lower than in stage N2 sleep and sometimes as low as in stage R sleep
- K complexes would be considered slow waves if they meet the definition of slow wave activity





Stage R

Definitions –

- **Rapid Eye Movements (REM)** - Conjugate, irregular, sharply peaked eye movements with an initial deflection usually lasting <500msec.
- **Low chin EMG tone** - Baseline EMG activity in the chin derivation no higher than in any other sleep stage and usually at the lowest level of the entire recording.

- **Saw tooth waves** - Trains of sharply contoured or triangular, often serrated, 2-6 Hz waves maximal in amplitude over the central head regions and often, but not always, preceding a burst of rapid eye movements.

- **Transient muscle activity** - Short irregular bursts of EMG activity usually with duration <0.25 seconds superimposed on low EMG tone.
- The activity may be seen in the chin or anterior tibial EMG derivations, as well as in EEG or EOG deviations, the latter indicating activity of cranial nerve innervated muscles.
- The activity is maximal in association with eye movements.

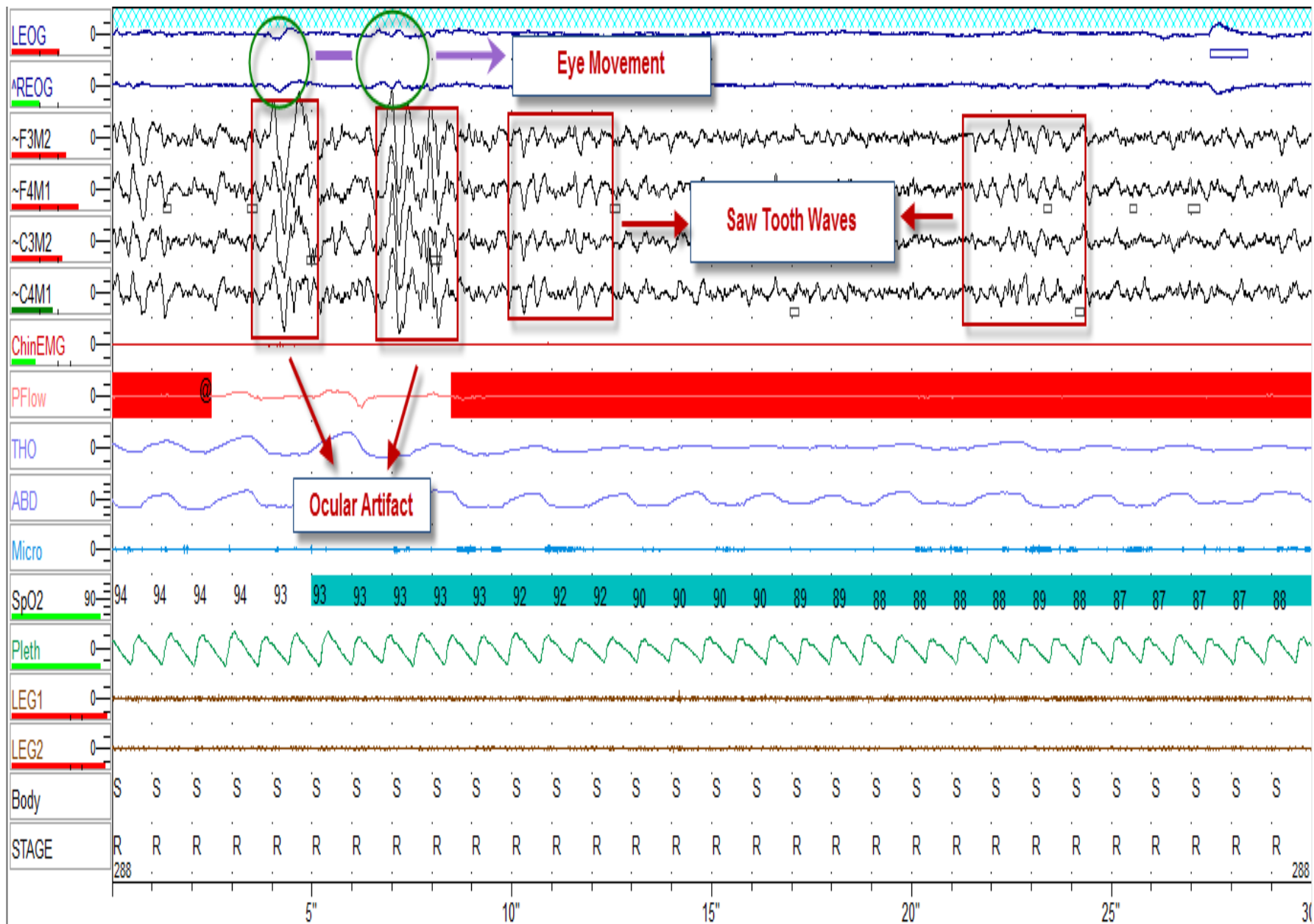
RULES –

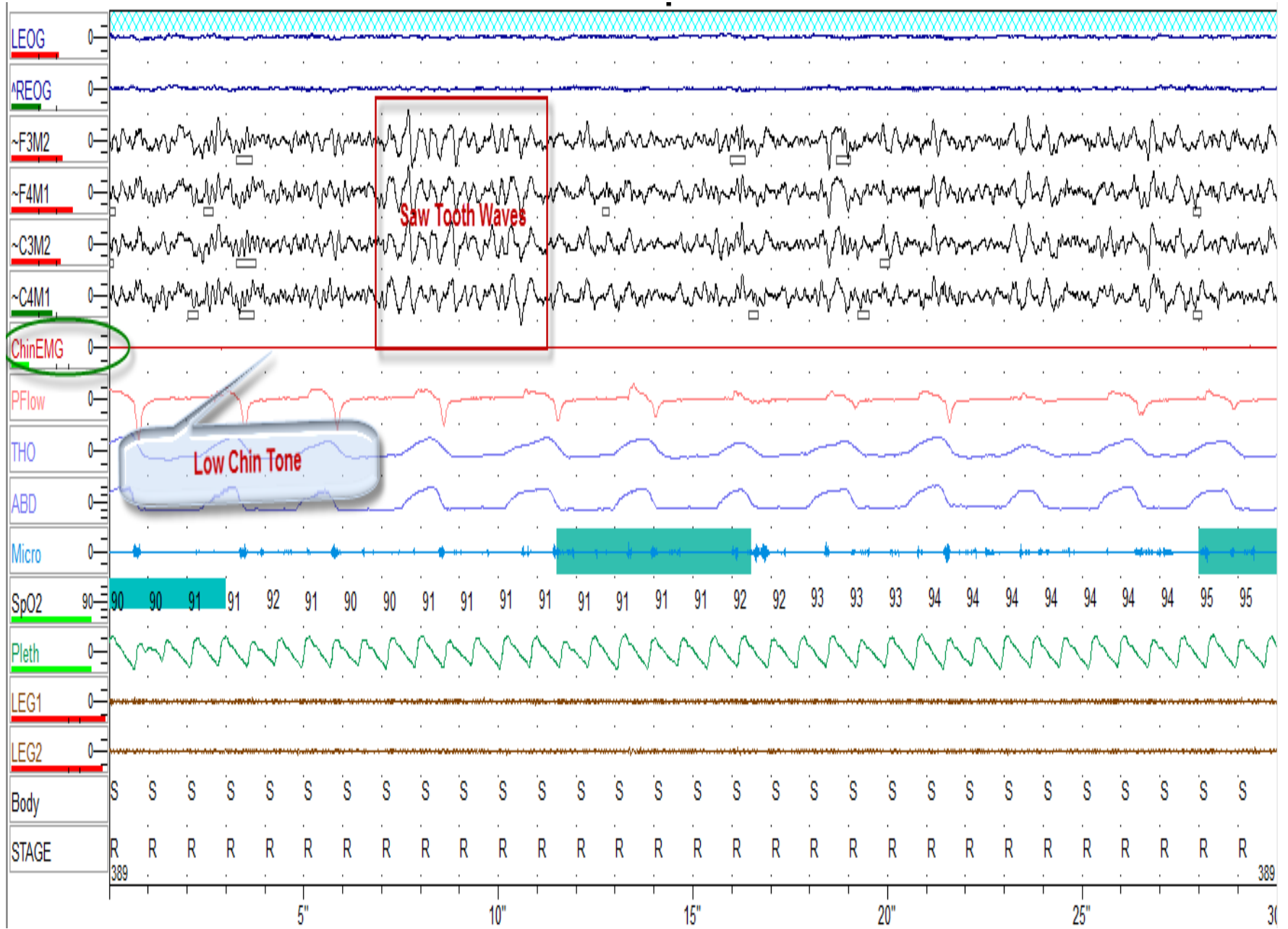
A. Score stage R sleep in epochs with all the following phenomena –

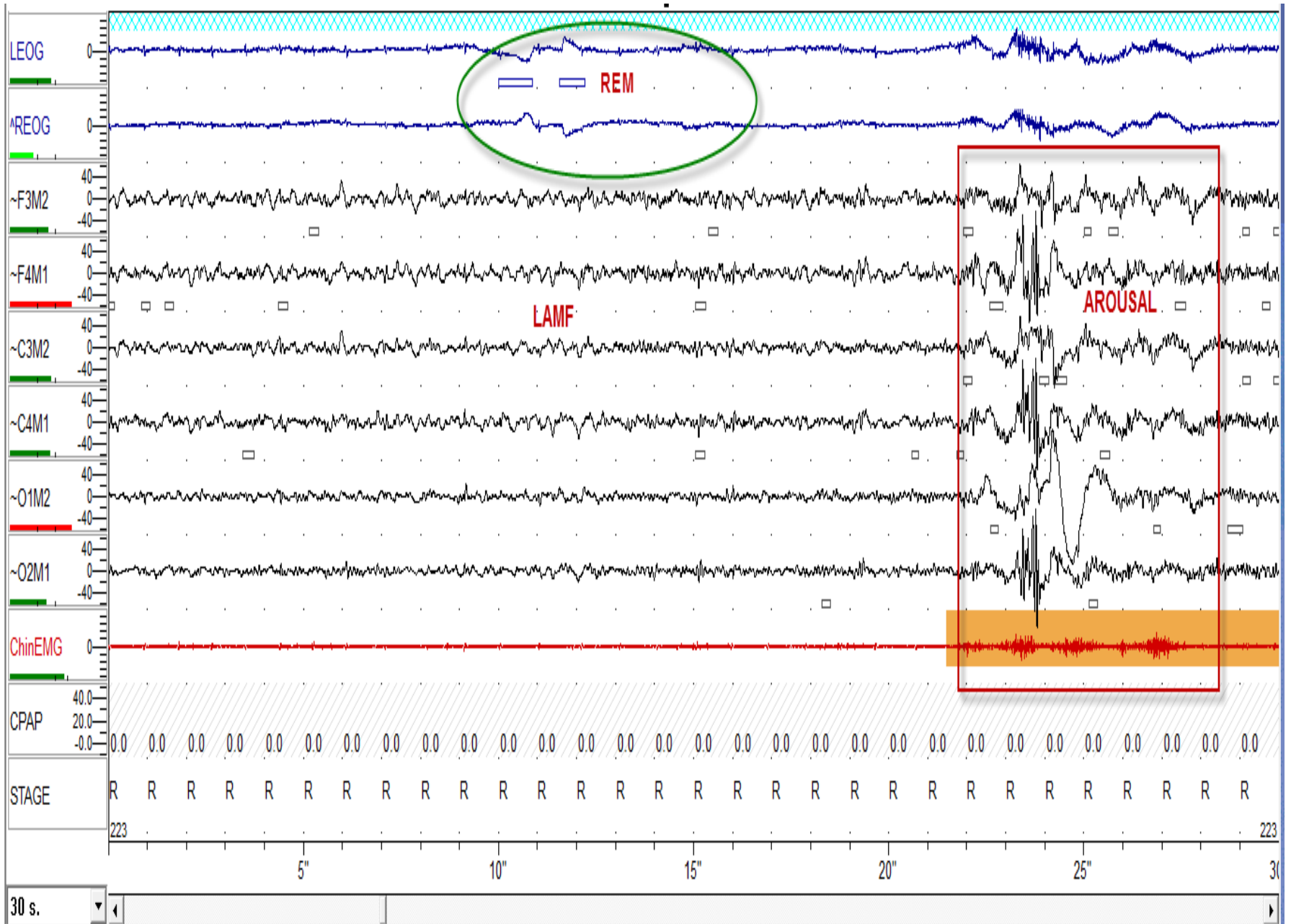
- Low amplitude mixed frequency EEG
- Low chin EMG tone
- Rapid eye movement

B. The following rule defines the continuation of a period of stage R sleep –

- Continue to score stage R sleep, even in the absence of rapid eye movements, for epochs following 1 or more epochs of stage R, if the EEG continues to show low amplitude, mixed frequency activity without K complexes or sleep spindles and the chin EMG tone remains low.

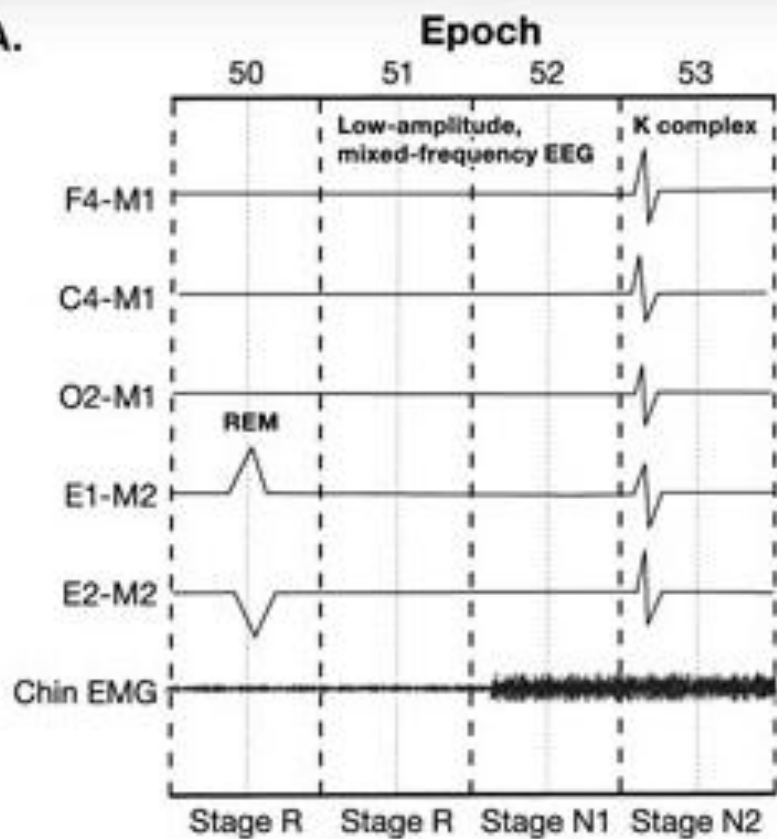
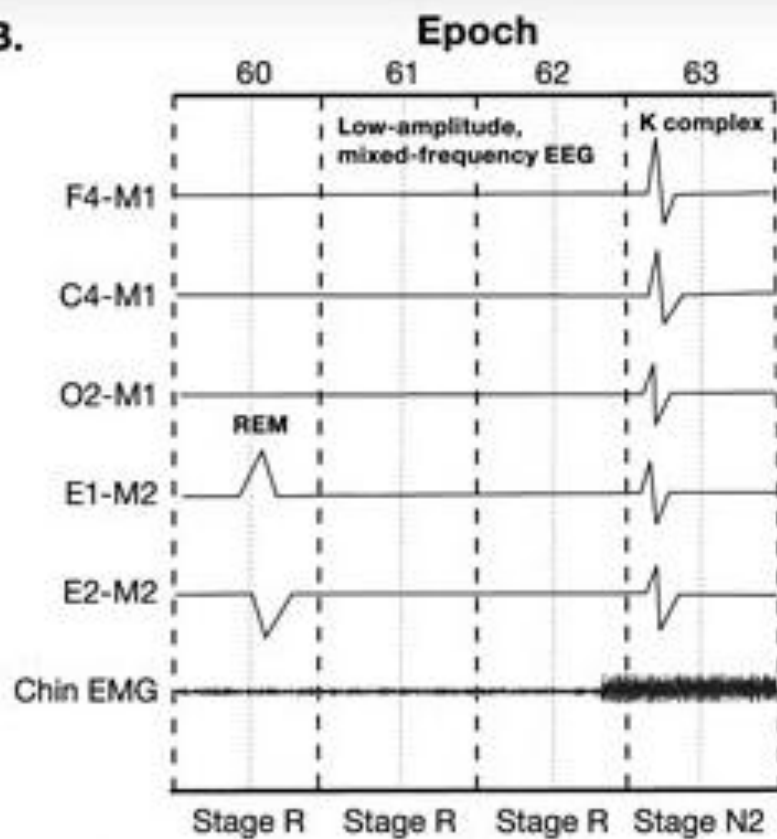




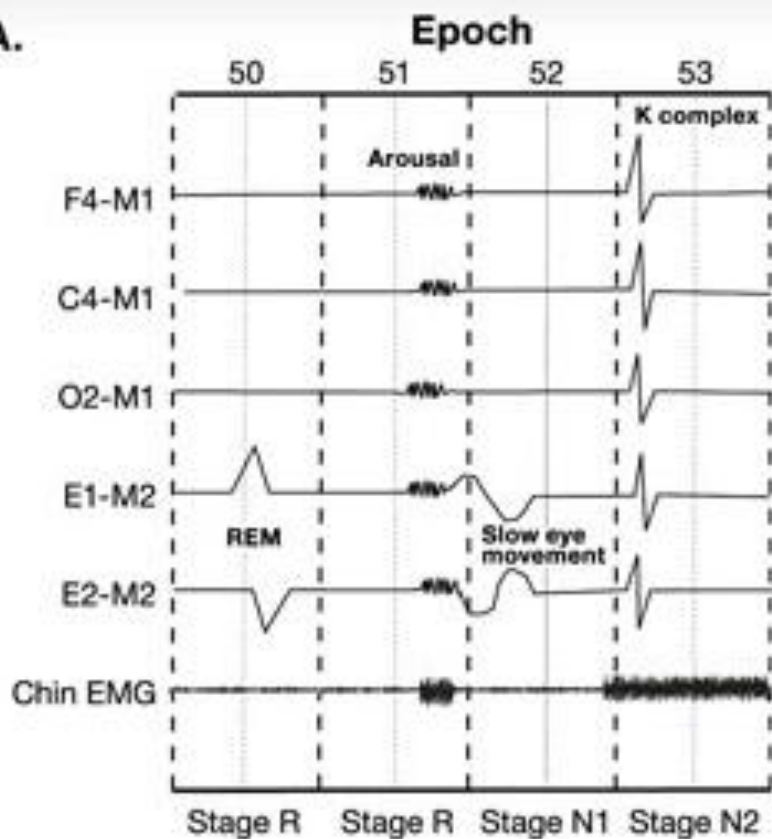
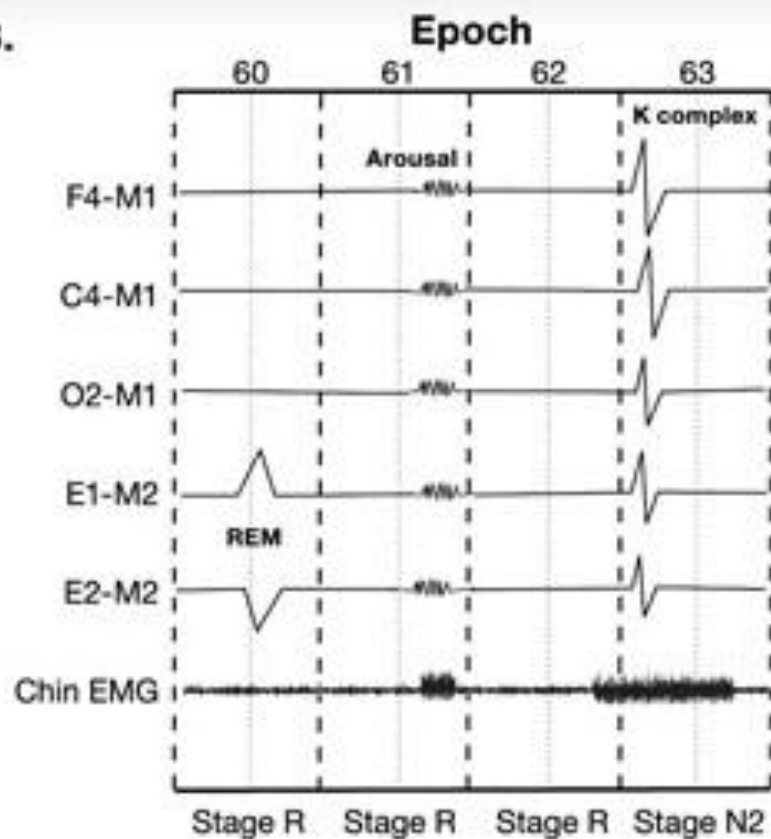


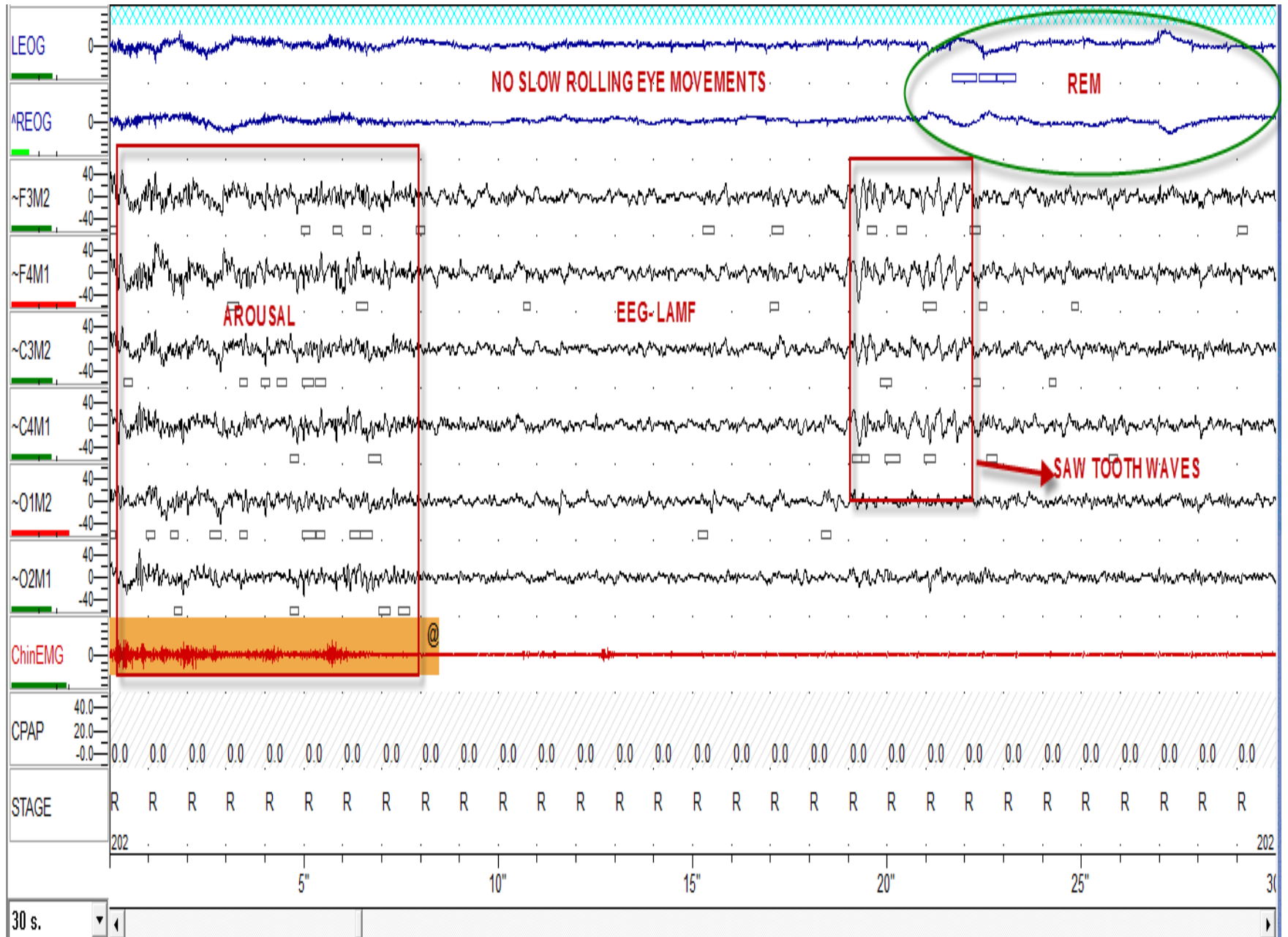
C. The following rule defines the end of a period of stage R sleep –

- Stop scoring stage R sleep when 1 or more of the following occur:
- There is a transition to stage W or N3
- An increase in chin EMG tone above the level of stage R is seen and criteria for stage N1 are met

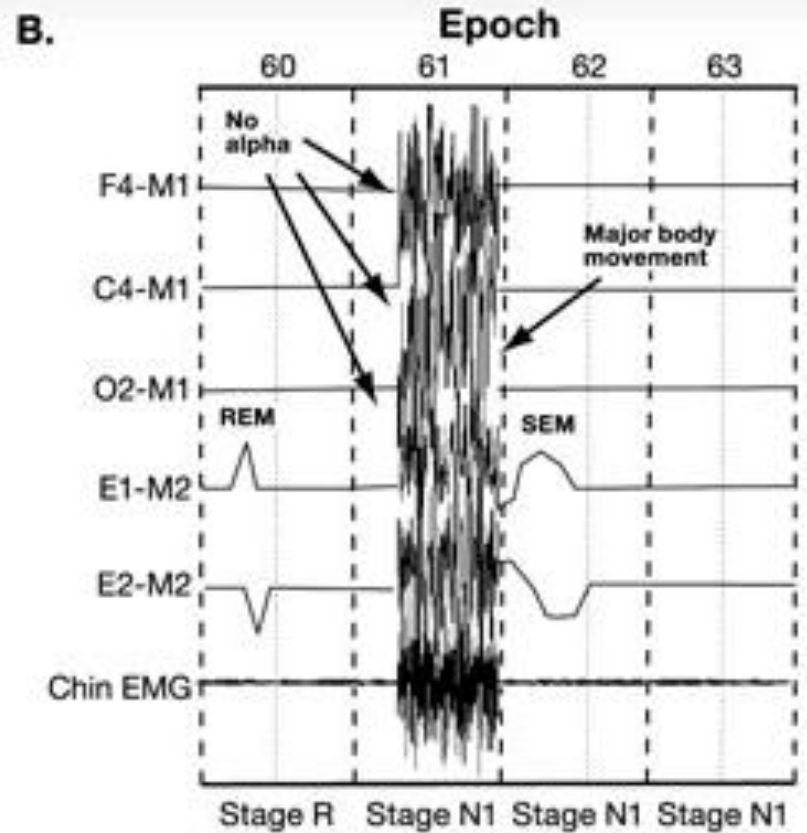
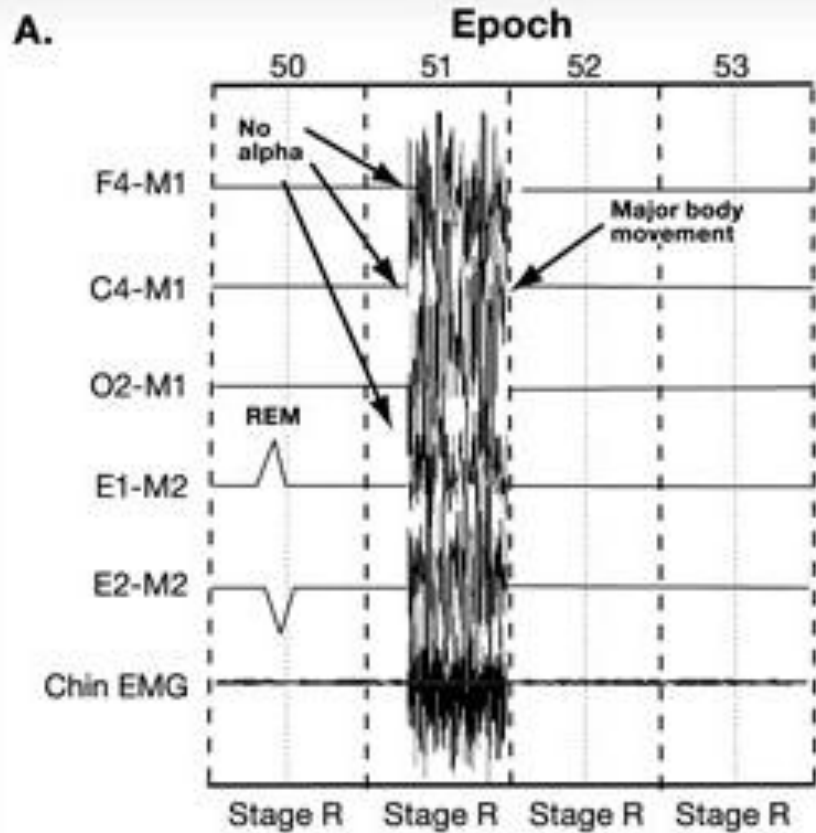
A.**B.**

- An arousal occurs followed by low amplitude, mixed frequency EEG and slow eye movements (score as stage N1; if no slow eye movements and chin EMG tone remains low, continue to score as stage R).

A.**B.**

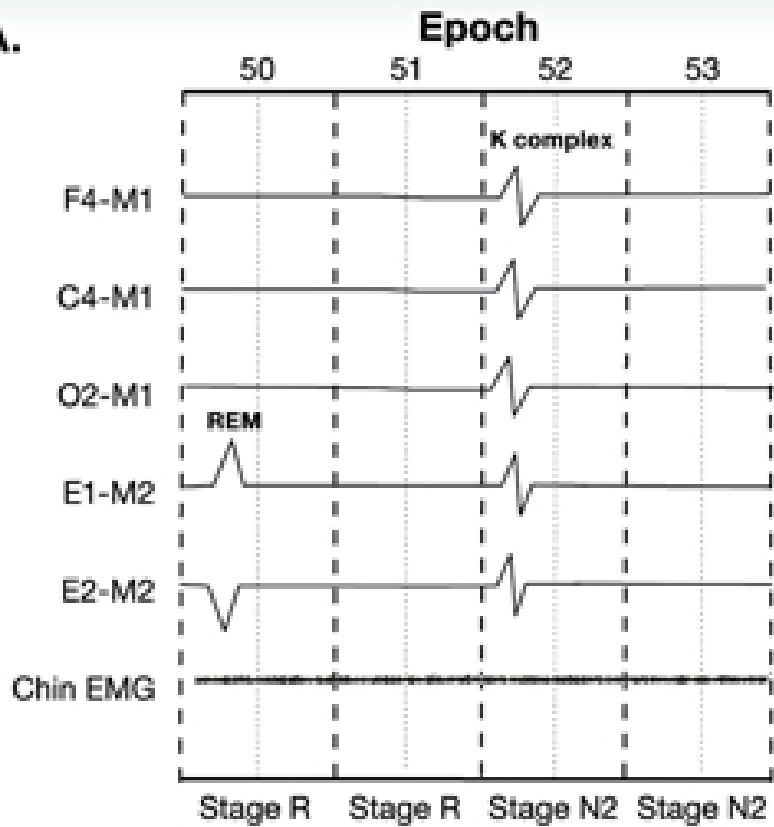


- A major body movements followed by slow eye movements and low amplitude mixed frequency EEG without non-arousal associated K complexes or sleep spindles (score the epoch following the major body movement as stage N1; if no slow eye movements and the EMG tone remains low, continue to score as stage R; the epoch containing the body movement is scored

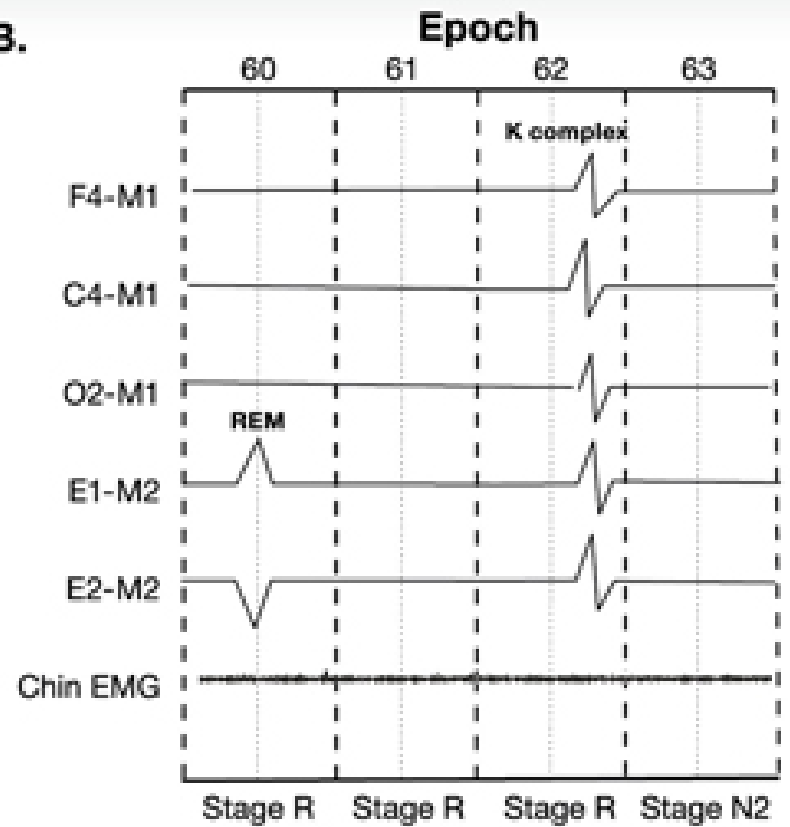


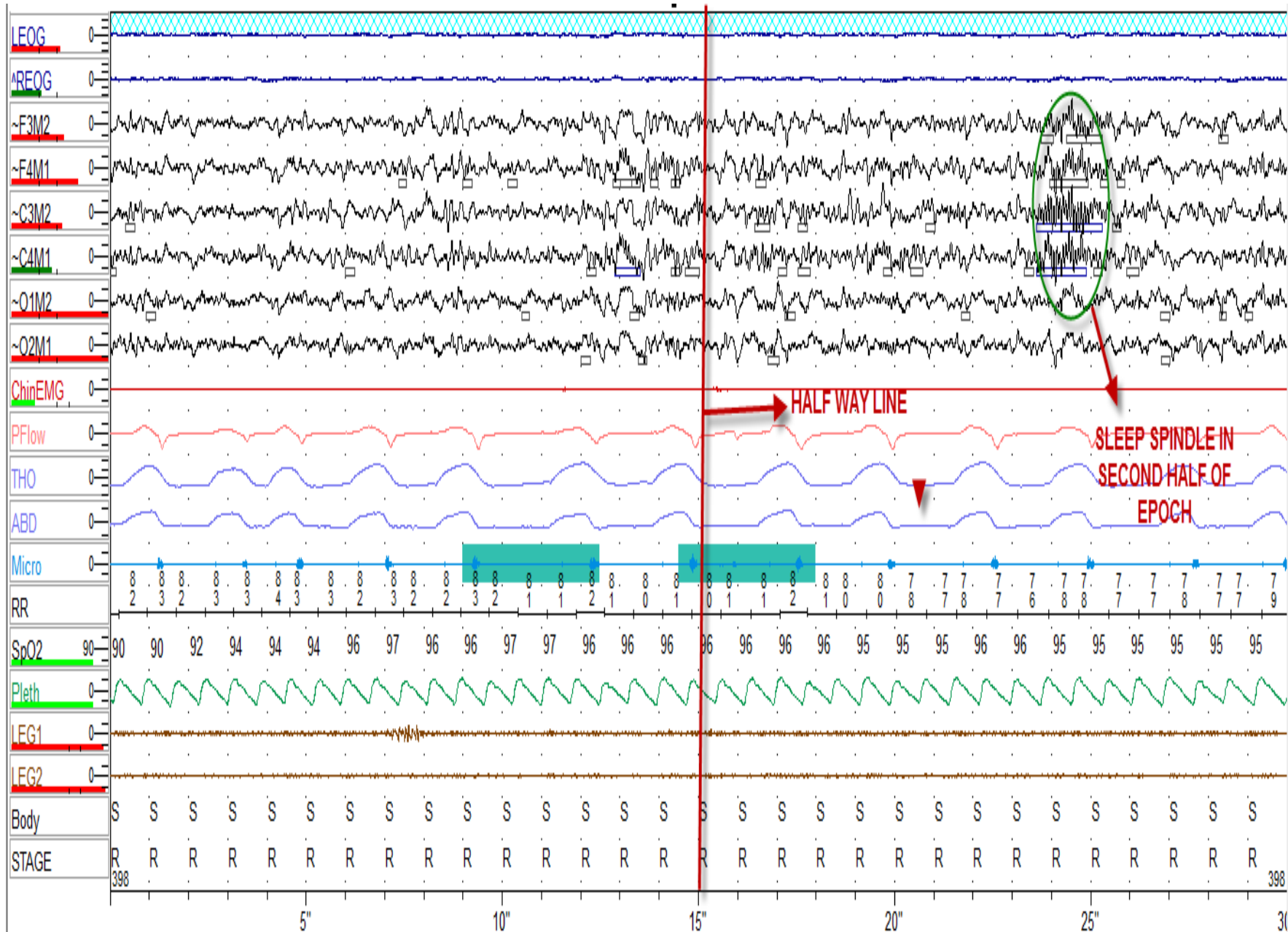
- One or more non-arousal associated K complexes or sleep spindles are present in the first half of the epoch in the absence of rapid eye movements, even if chin EMG tone remains low (score as stage N2).

A.



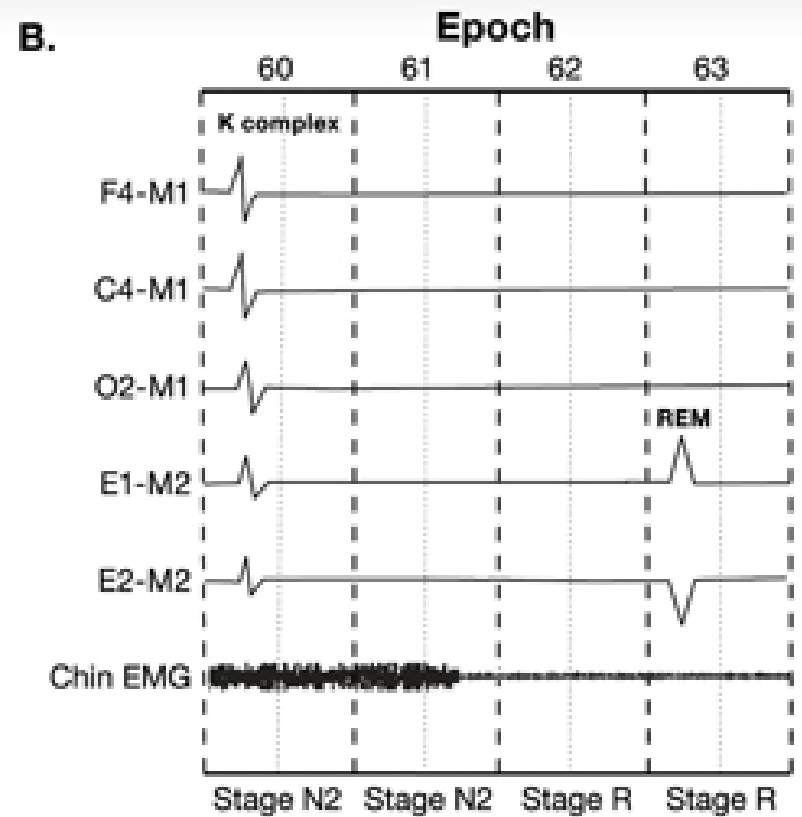
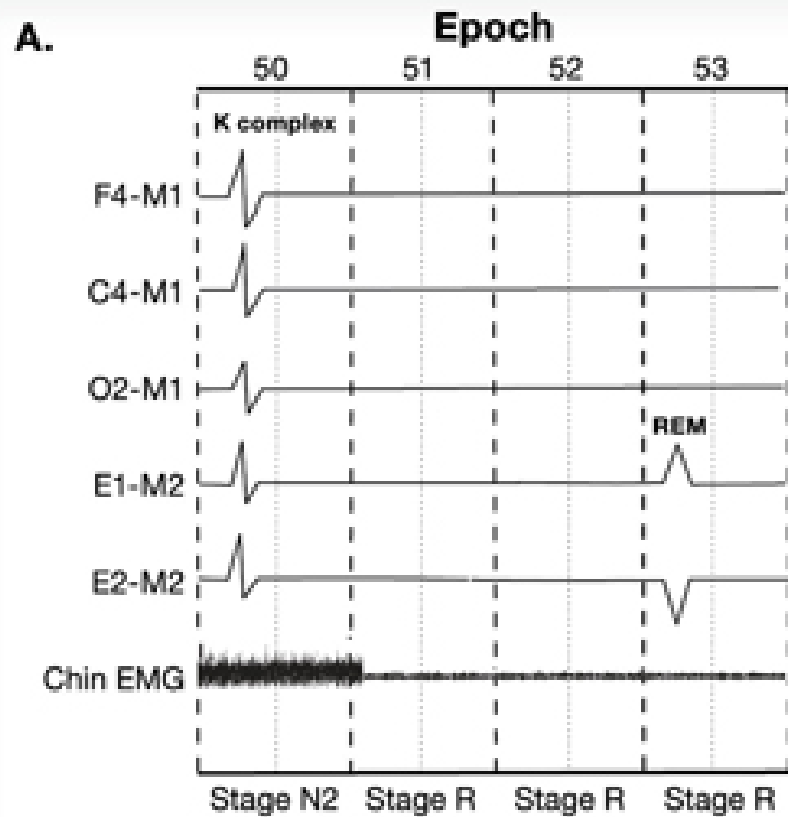
B.





D. Score epochs at the transition between stage N2 and stage R as follows –

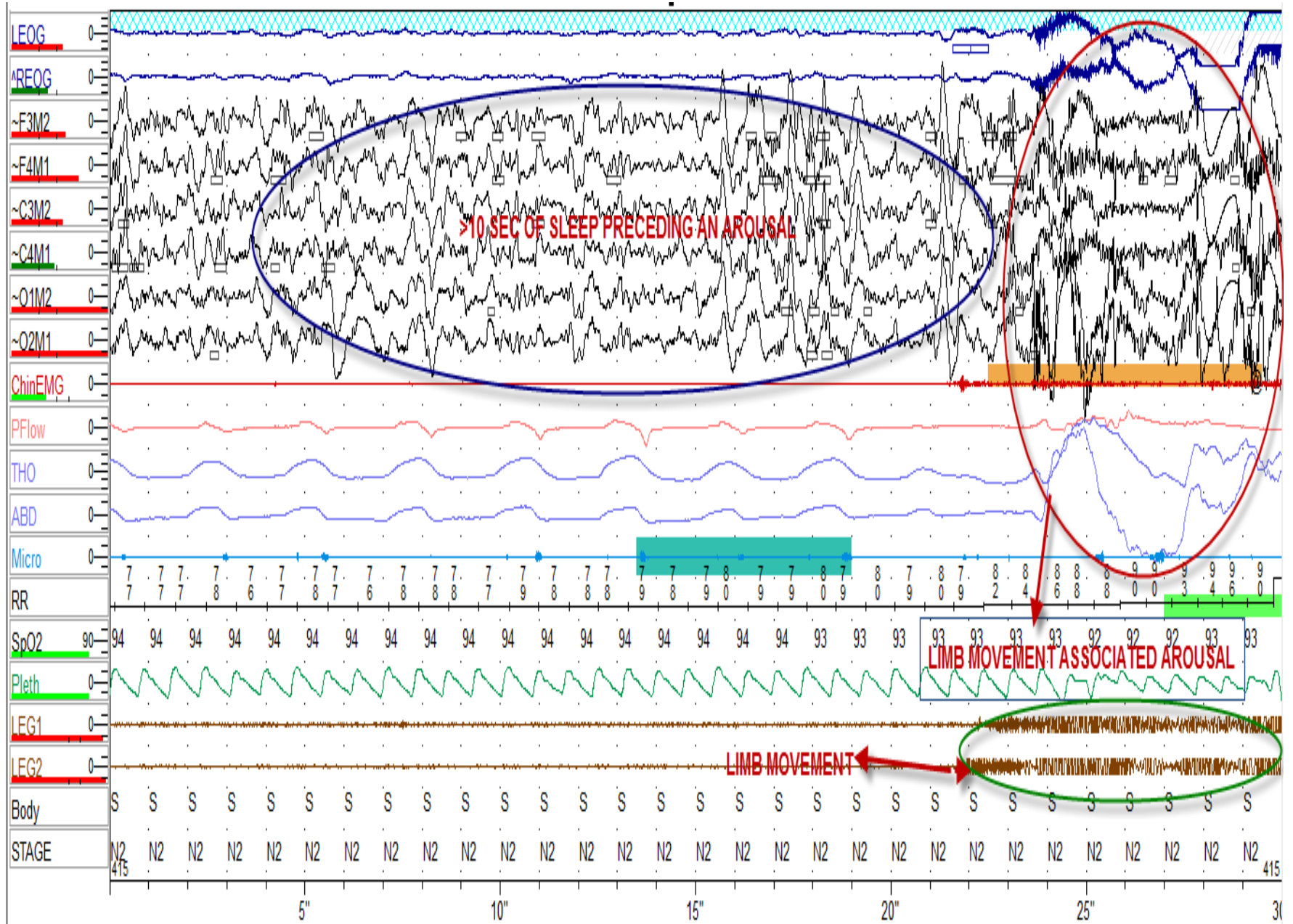
1. In between epochs of definite stage N2 and definite stage R, score an epoch with a distinct drop in chin EMG in the first half of the epoch to the level seen in stage R as stage R if all of the following criteria are met, even in the absence of rapid eye movements.
 - ❑ Absence of non-arousal associated K complexes
 - ❑ Absence of sleep spindles

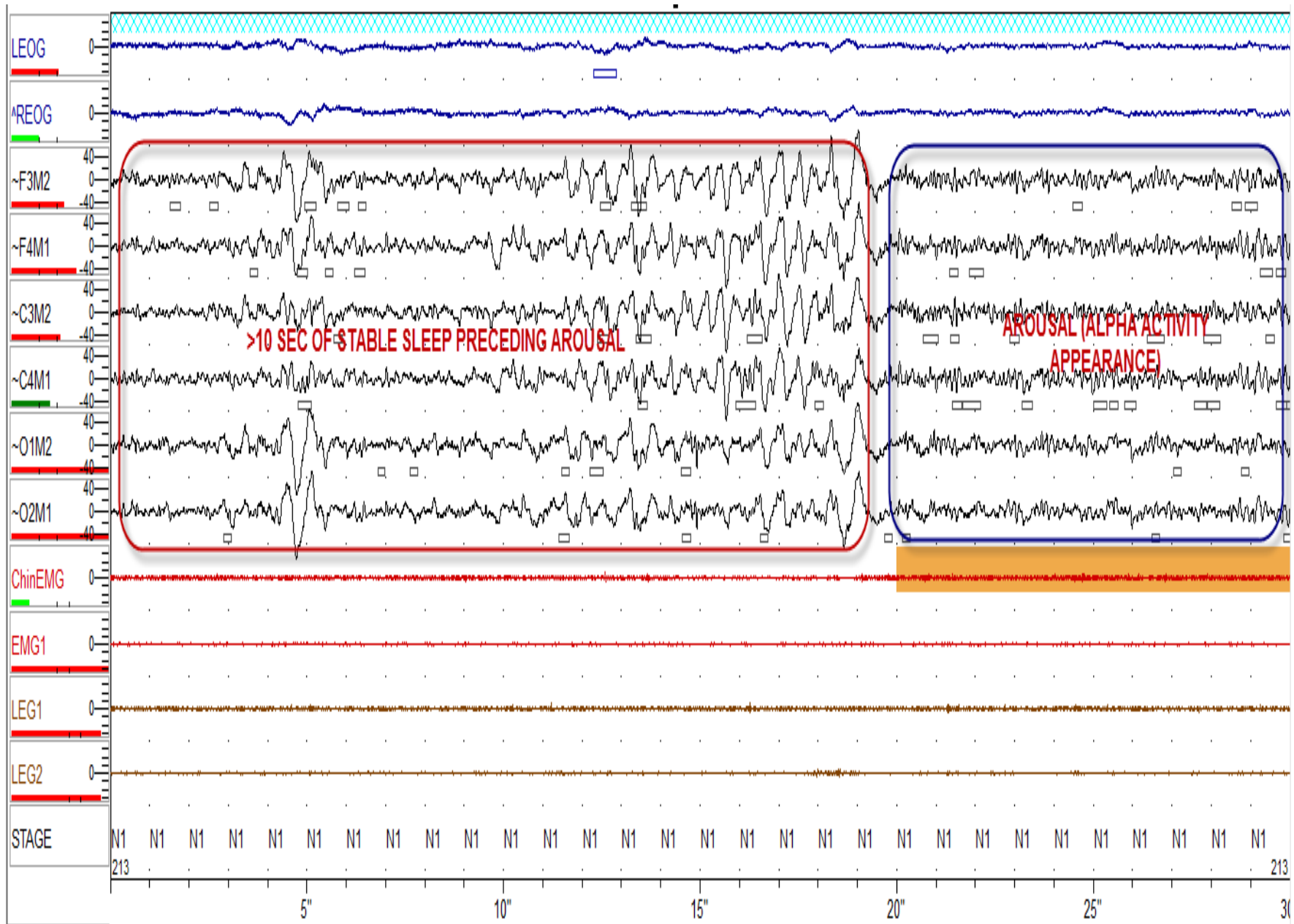


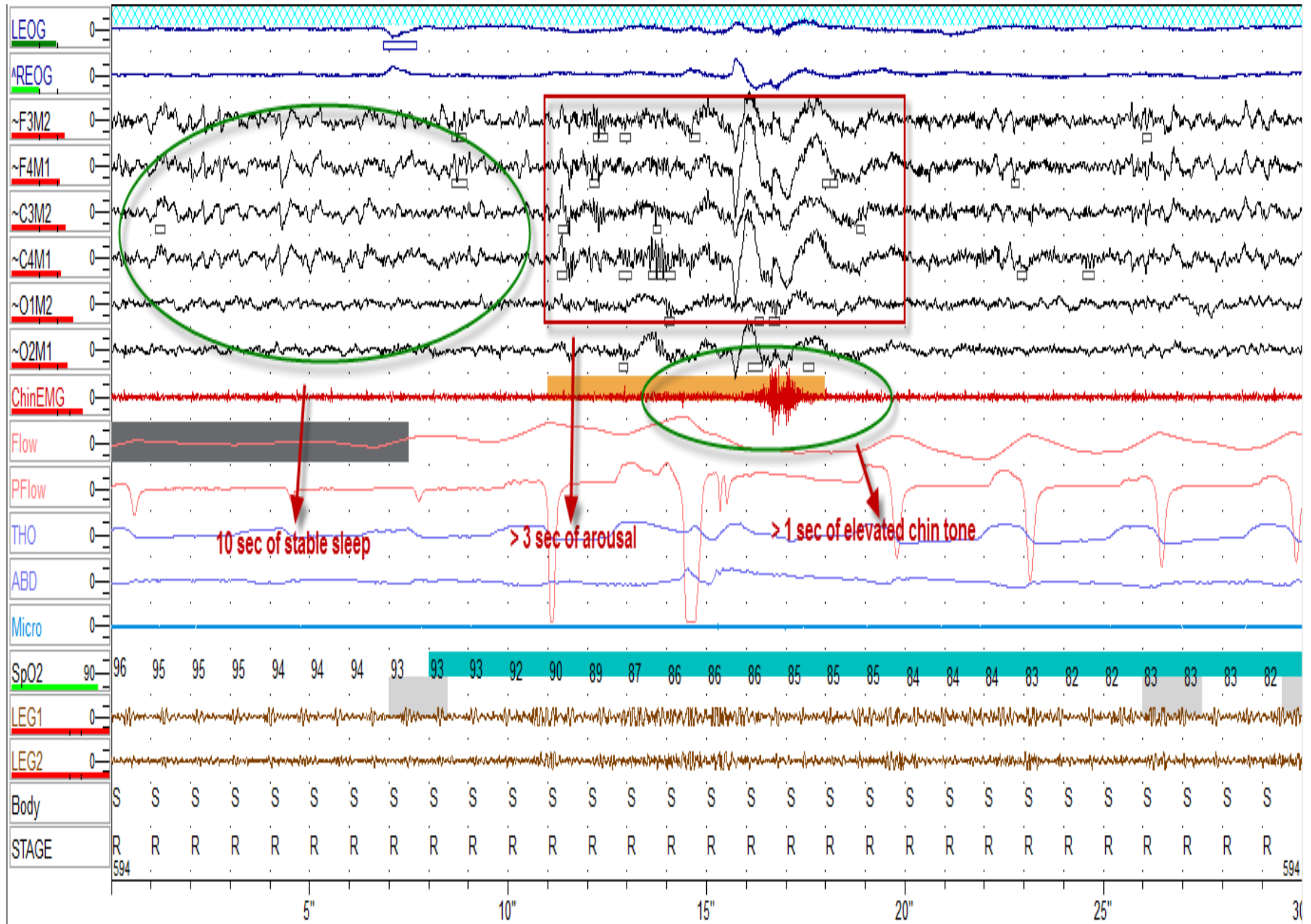
Arousal Rules

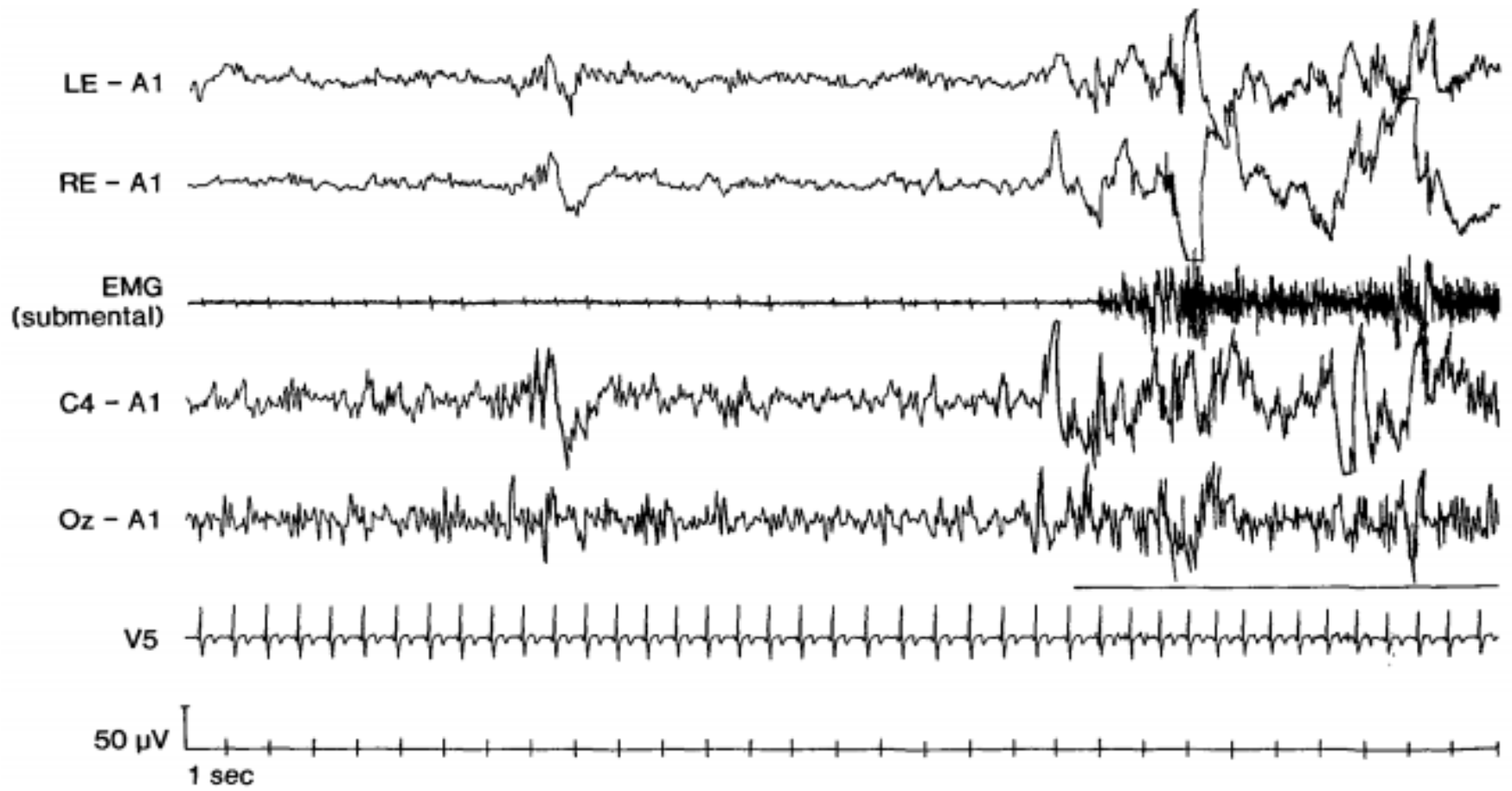
Scoring Arousal –

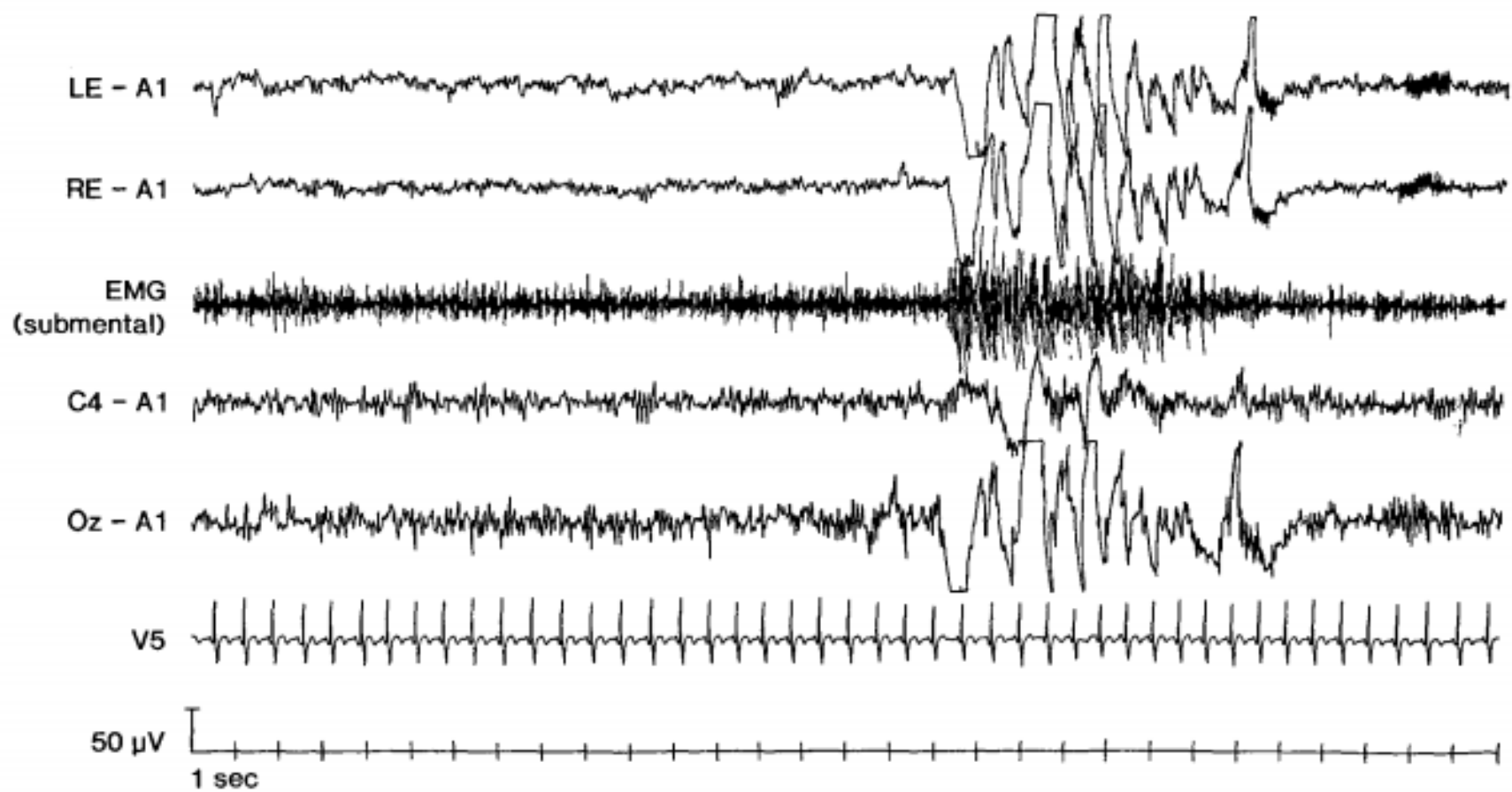
- Score arousal during sleep stages N1, N2, N3 or R if there is an abrupt shift of EEG frequency including alpha, theta and/or frequencies greater than 16 Hz (but not spindles) that lasts at least 3 seconds, with at least 10 seconds of stable sleep preceding the change
- Scoring of arousal during REM requires a concurrent increase in submental EMG lasting at least 1 second

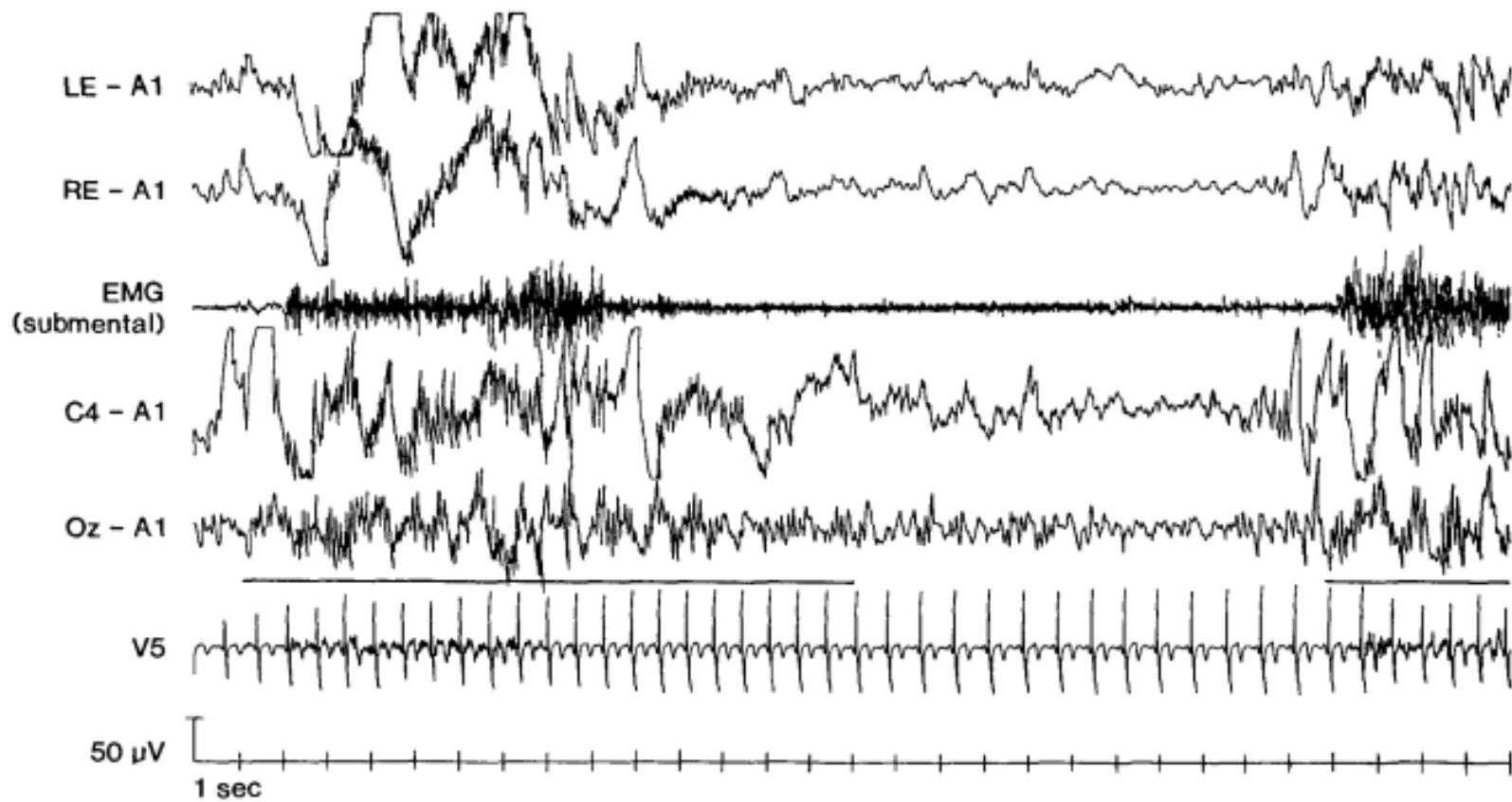


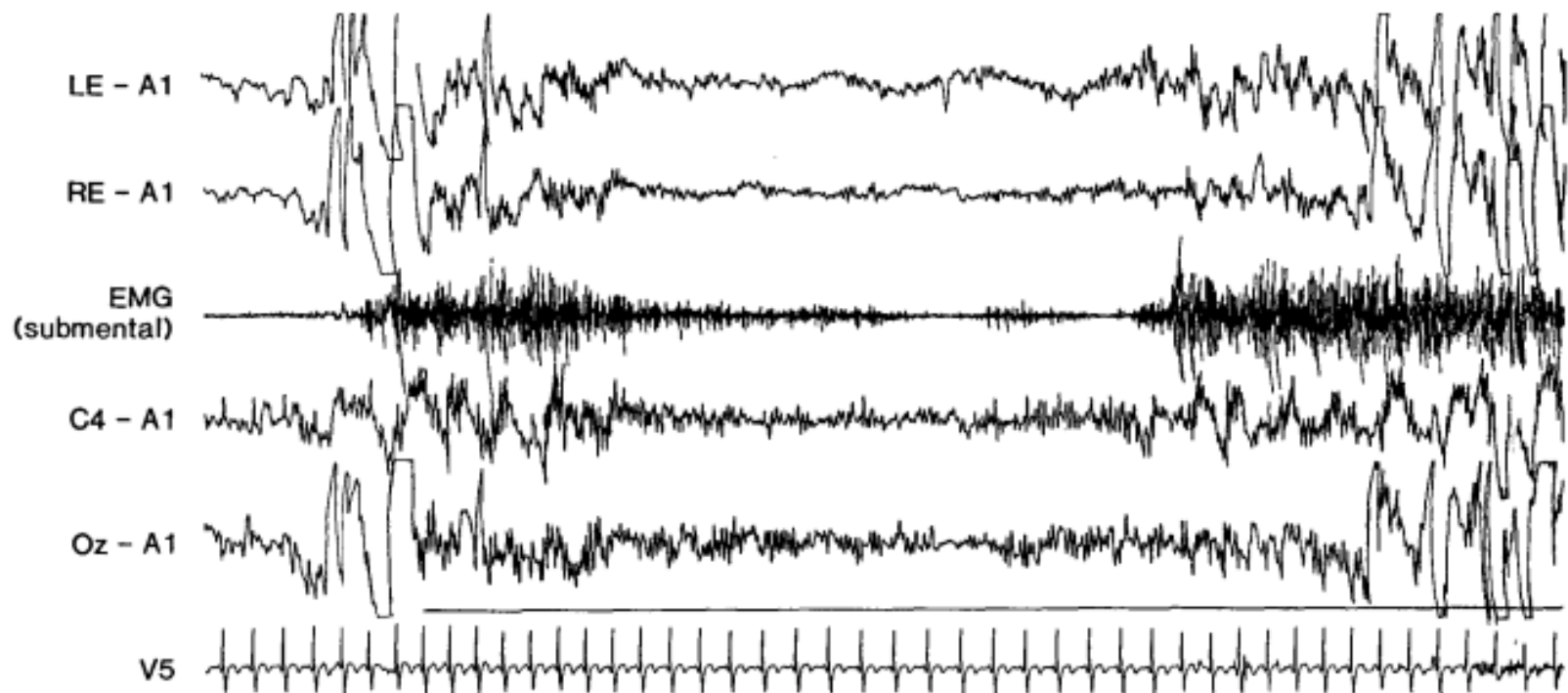


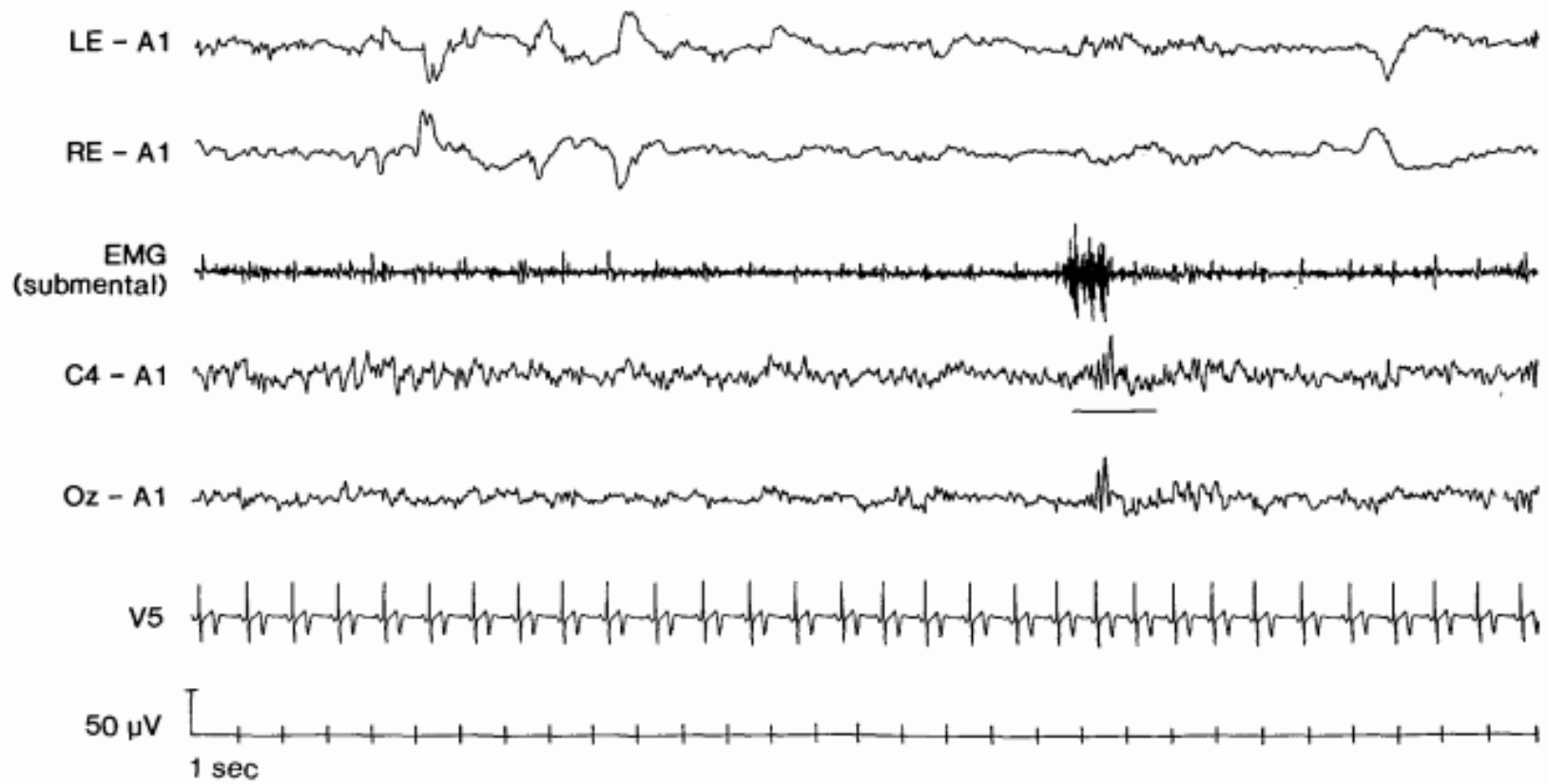


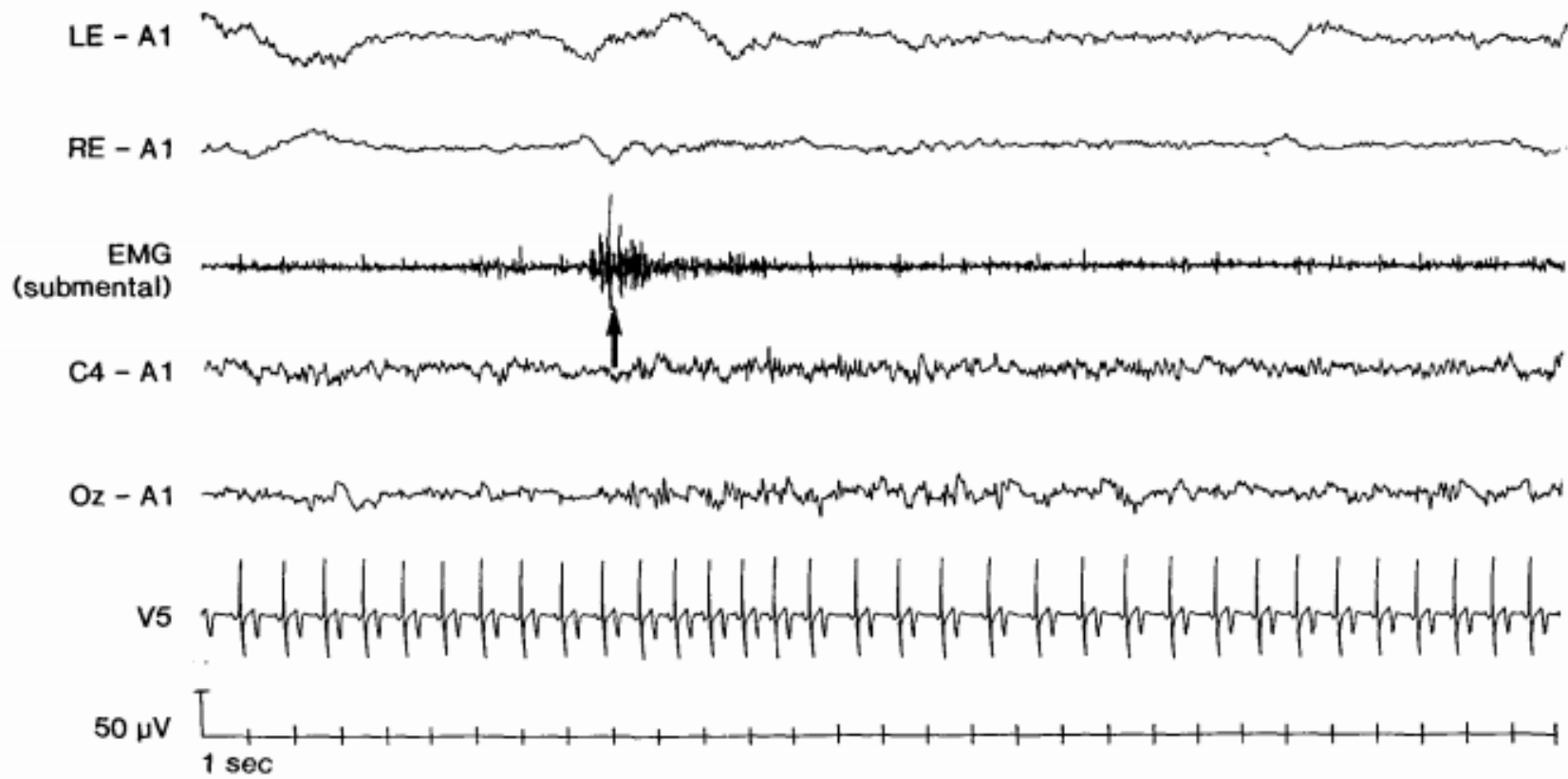


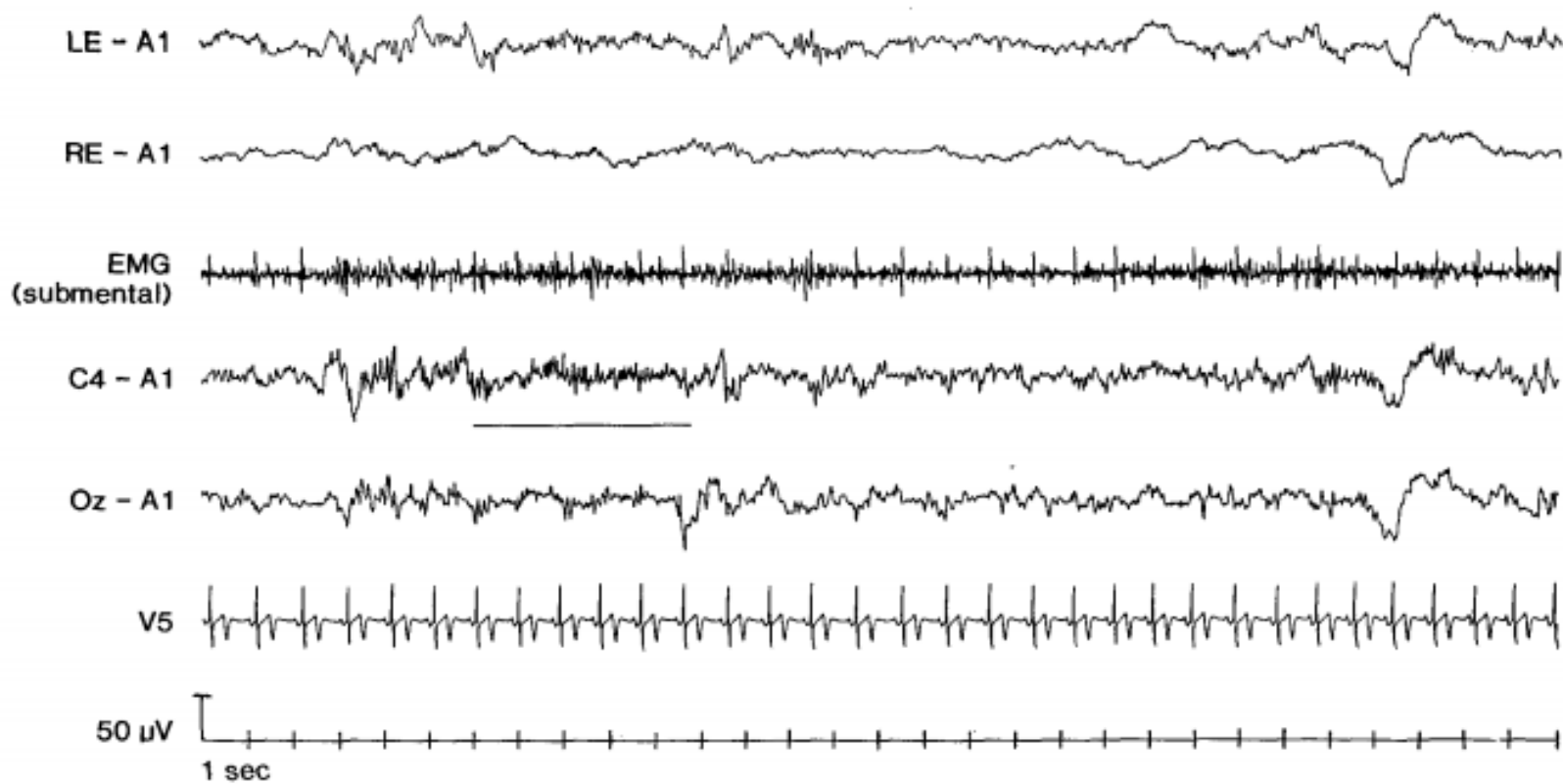


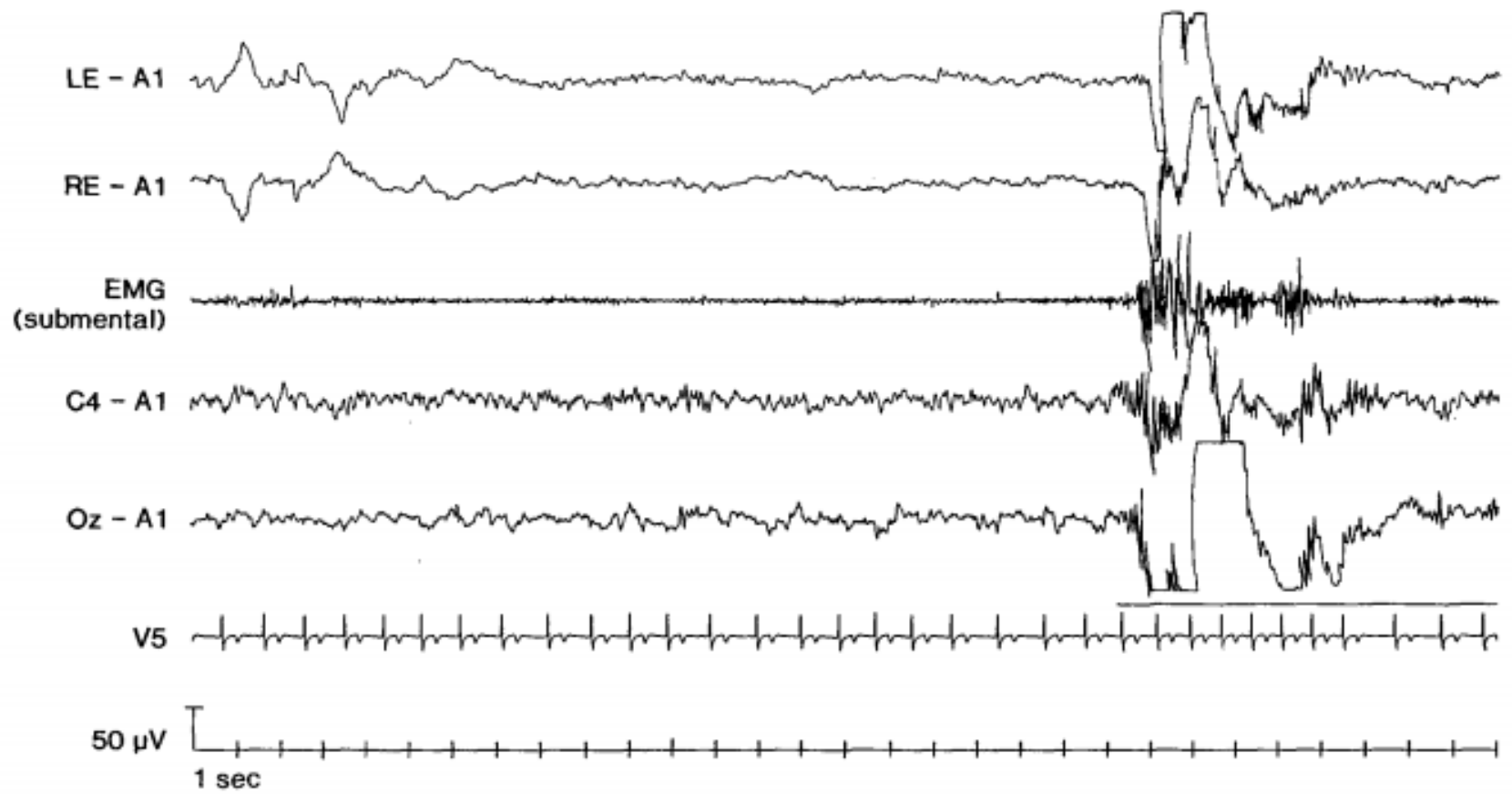


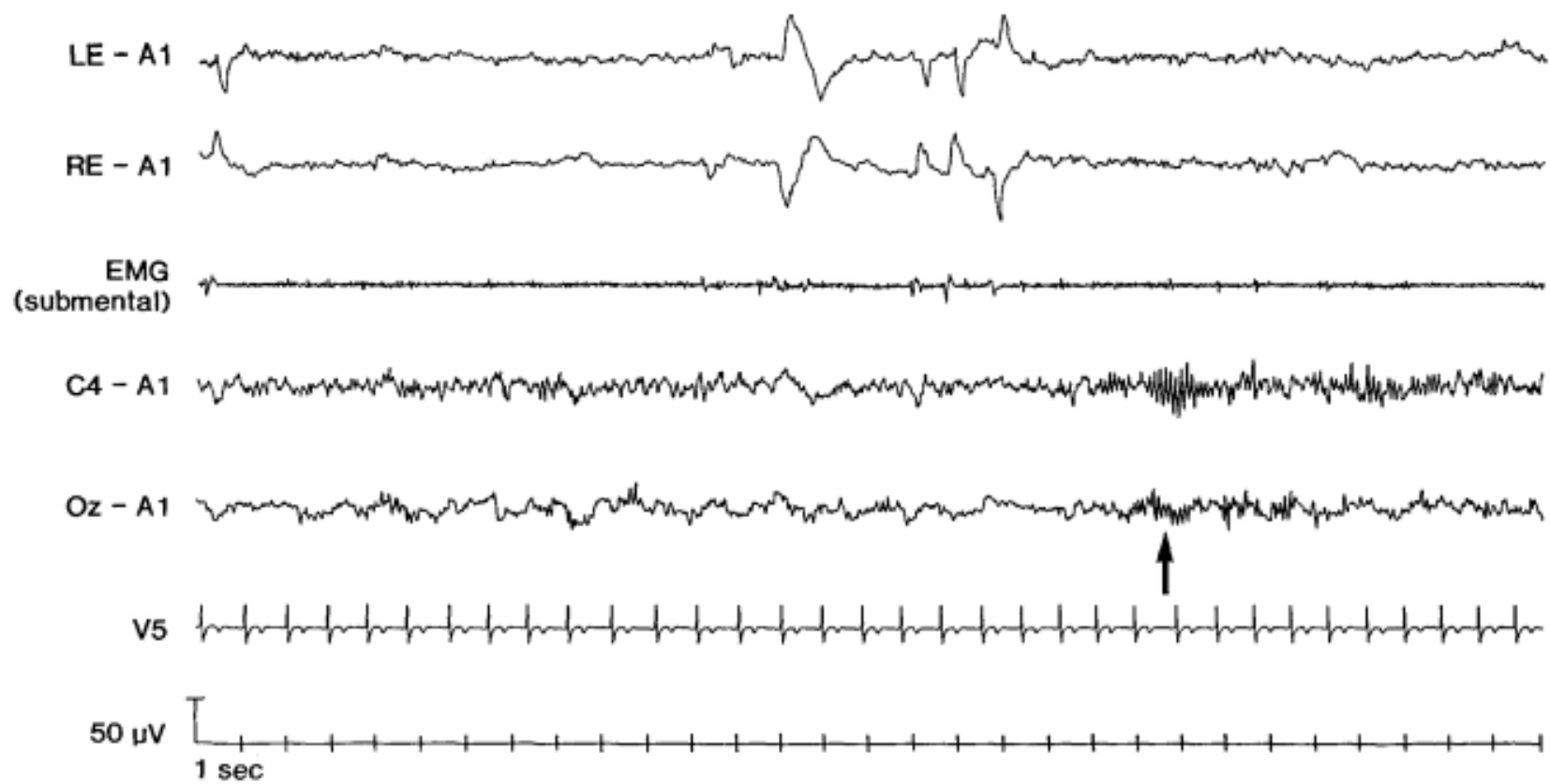


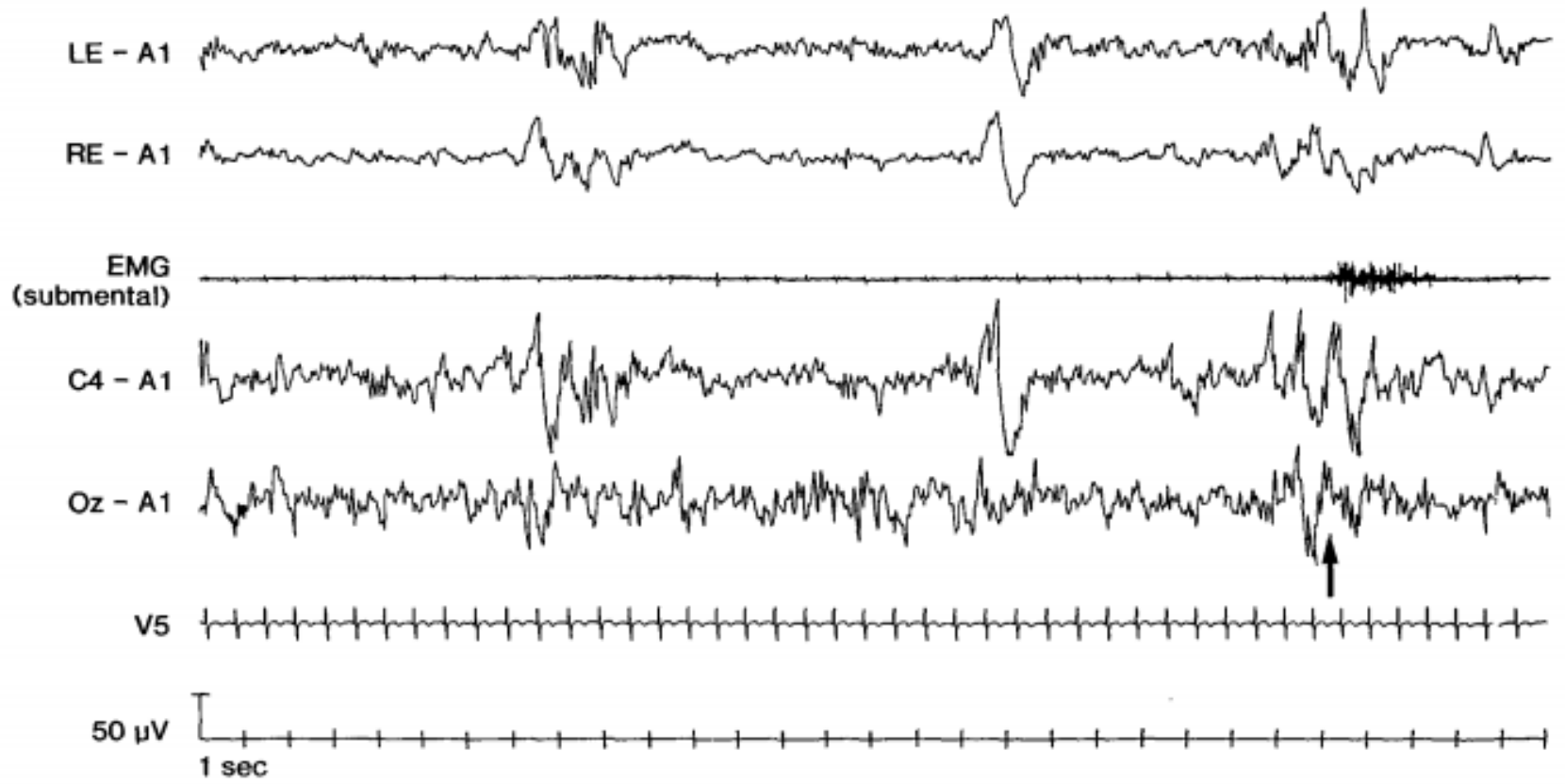


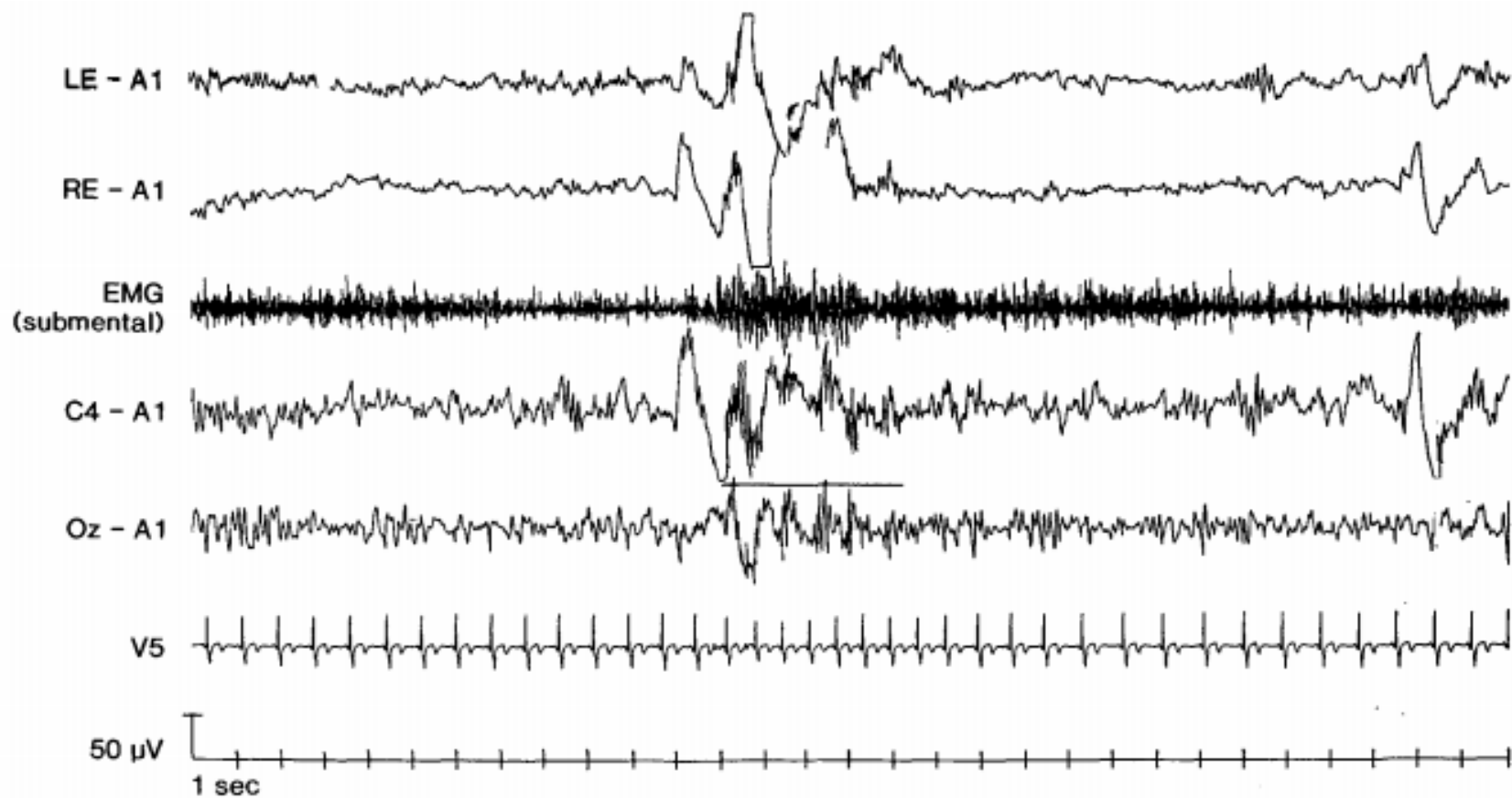


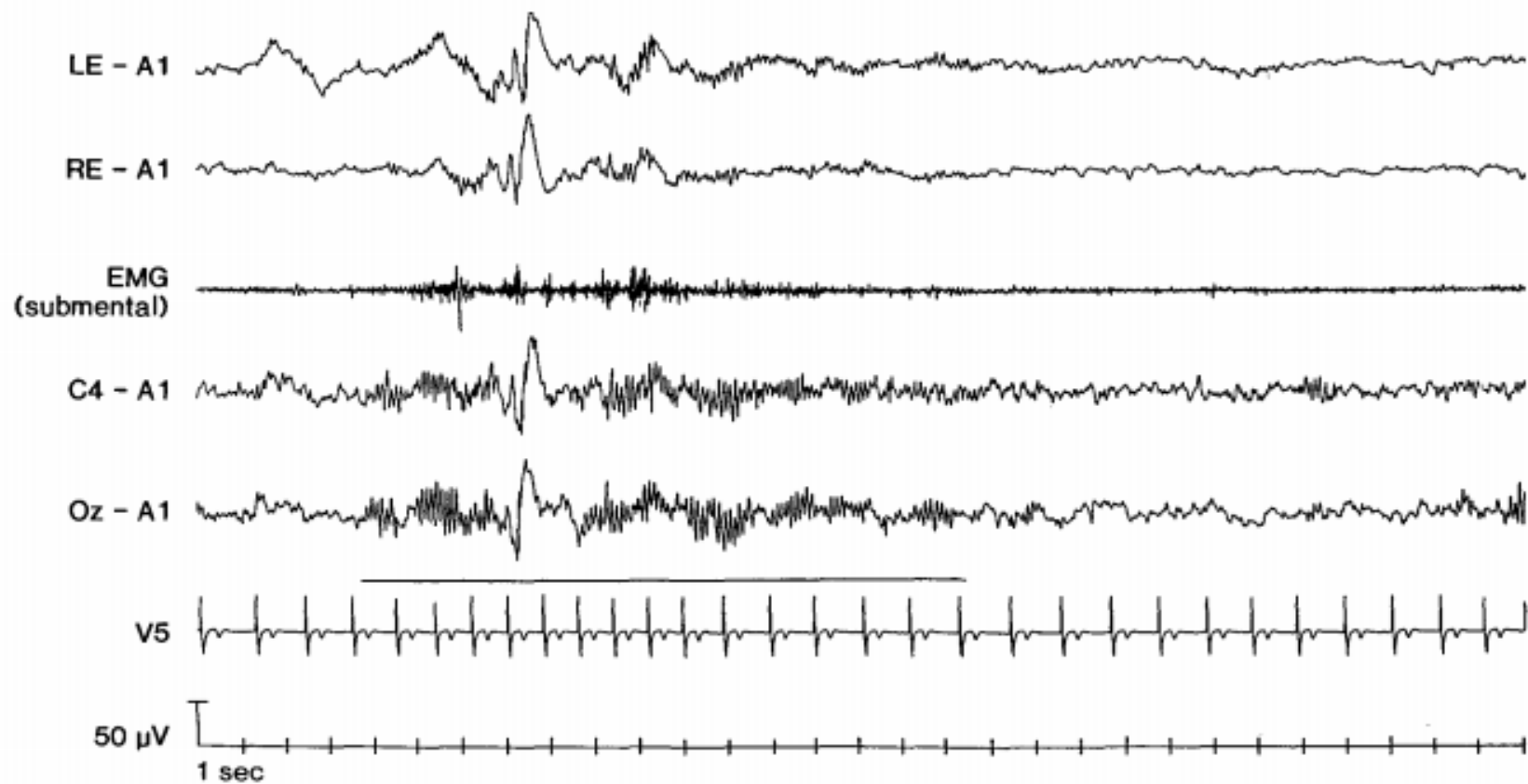


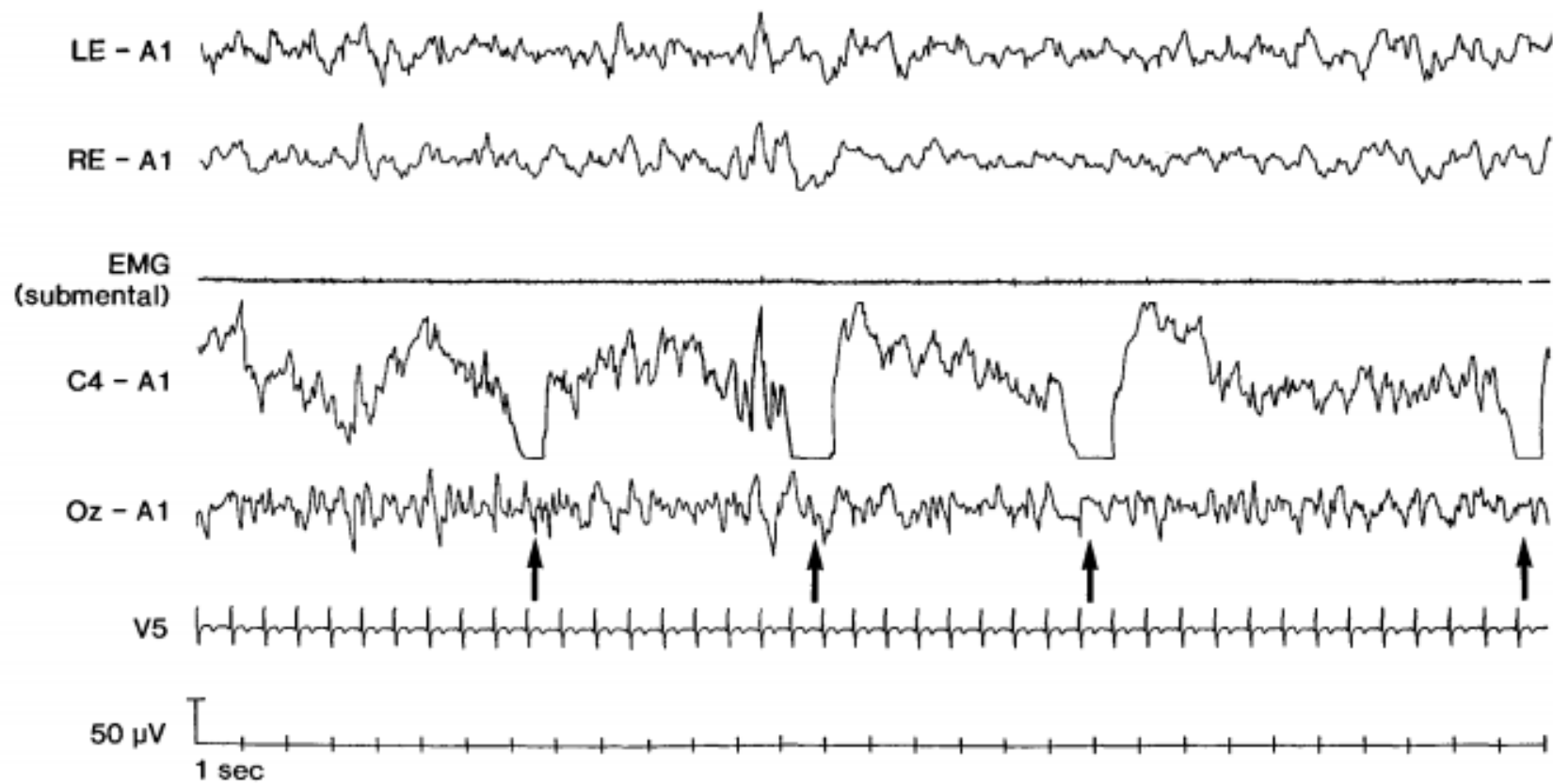


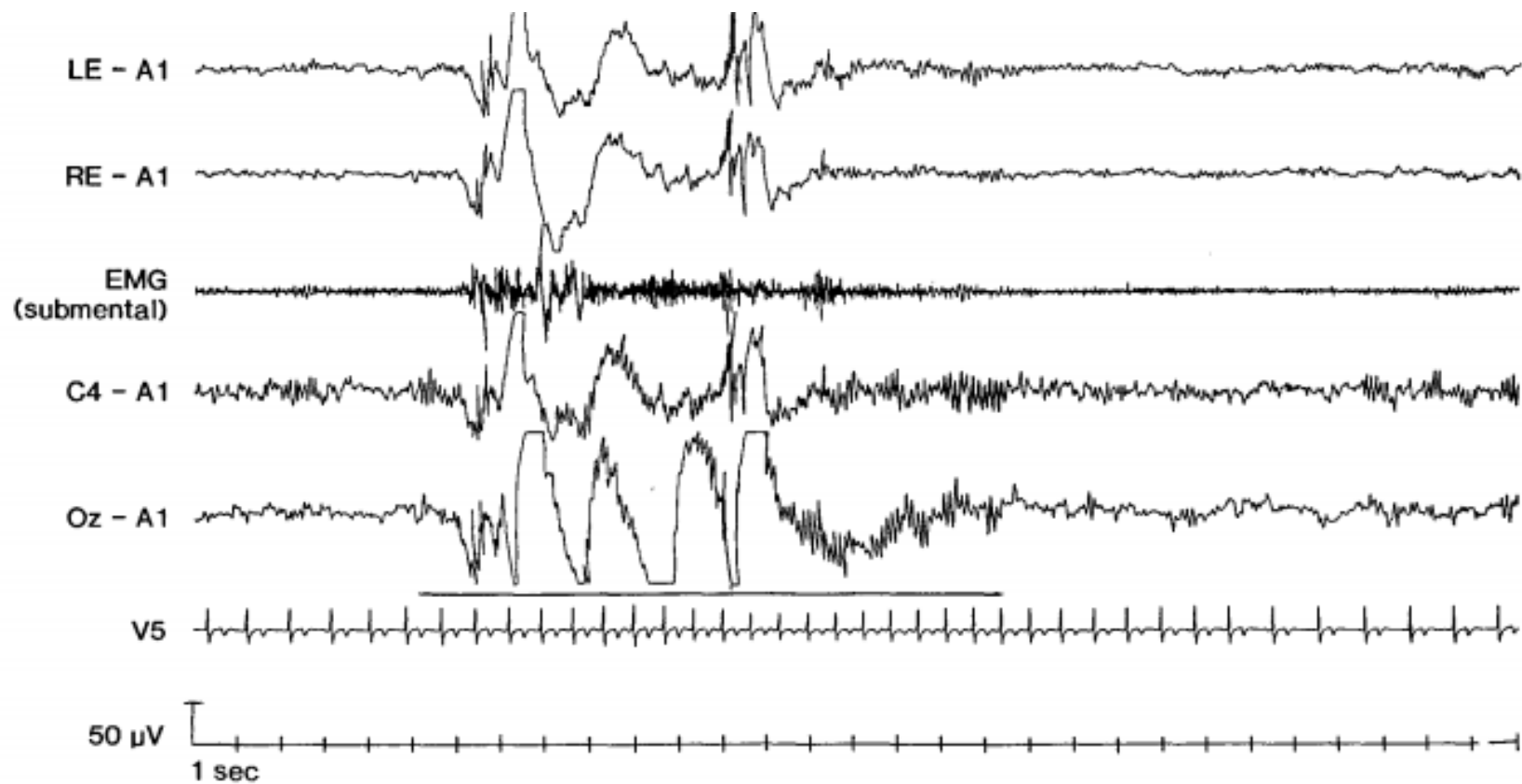


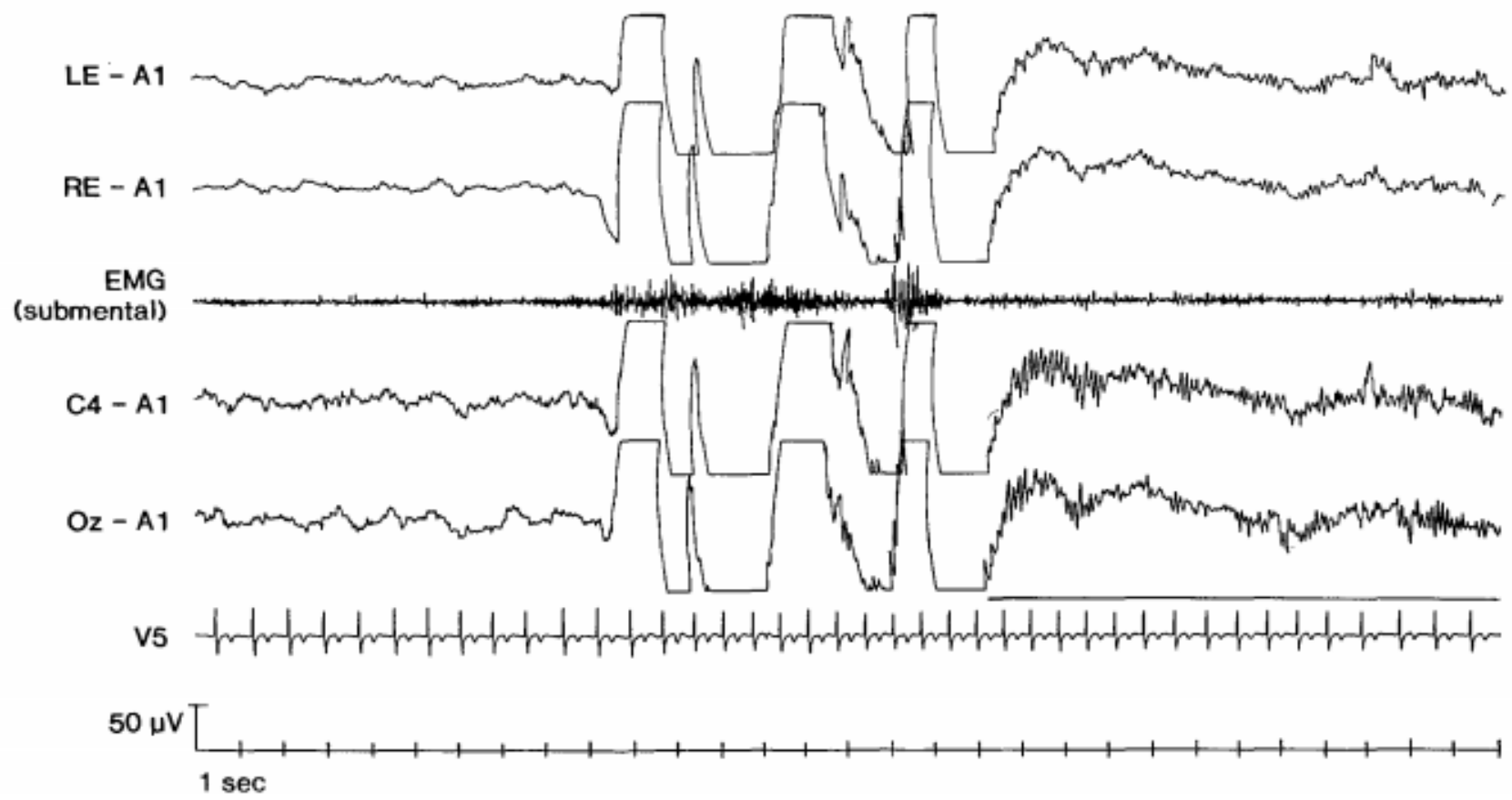


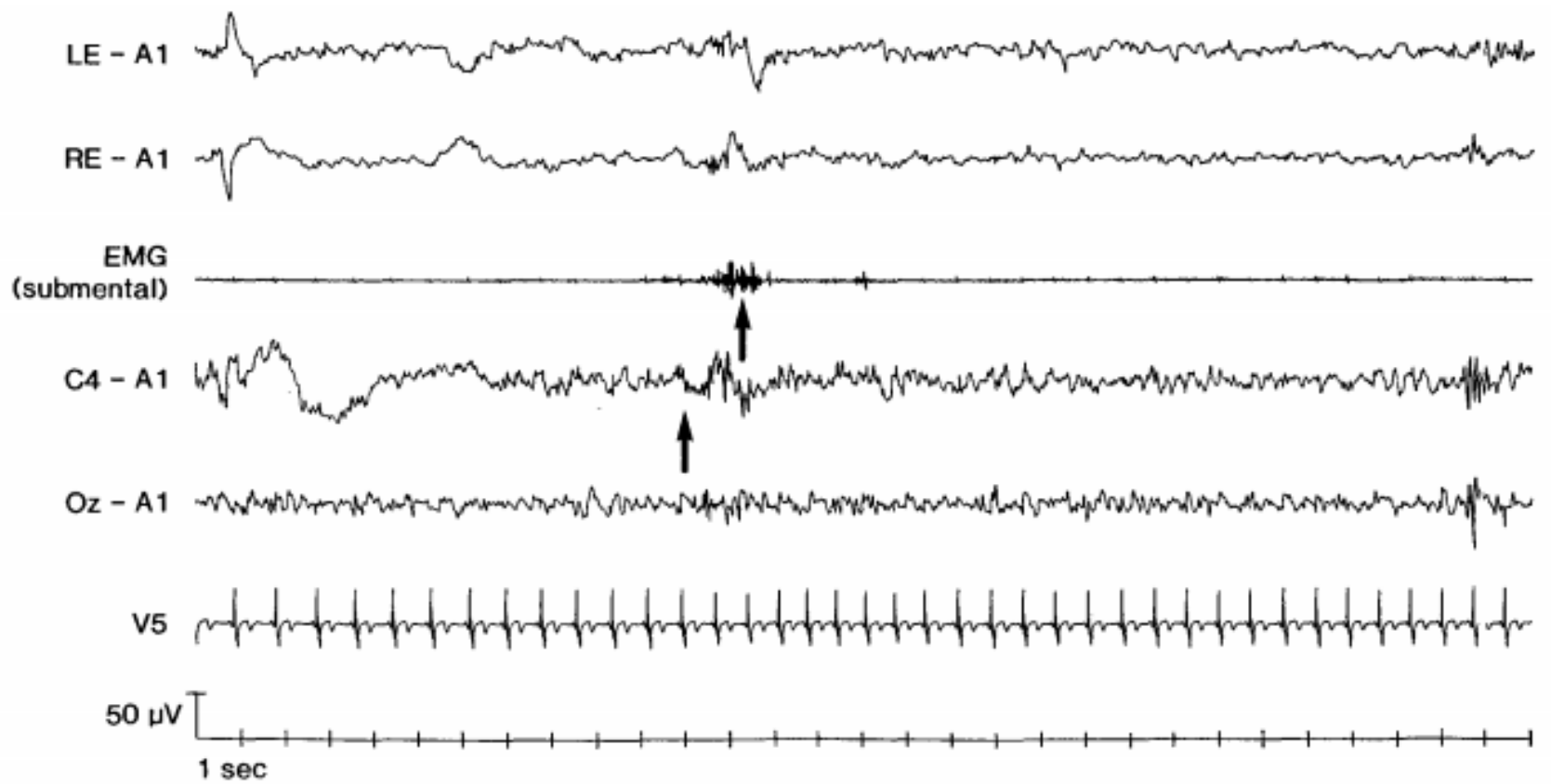












Major Body Movements –

Definitions –

- Major body movements: Movements and muscle artefact obscuring the EEG for more than half an epoch to the extent that the sleep stage cannot be determined.

Rules –

- Score an epoch with a major body movements as follows -
 - If alpha rhythm is present for part of the epoch (even <15 seconds duration), score as stage W

- If no alpha rhythm is discernable, but an epoch scorable as stage W either preceded or follows the epoch with a major body movement, score as stage W.
- Otherwise, score the epoch as the same stage as the epoch that follows it.