



Scoring Sleep Staging & Arousals

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Sleep Stage

- Sleep
 - NREM (non-rapid eye movement)
 - REM (rapid eye movement)

	R&K	AASM
Wake	Stage W	Stage W
NREM	Stage 1	Stage N1
	Stage 2	Stage N2
	Stage 3	Stage N3
	Stage 4	
REM	Stage REM	Stage R

AASM, American Academy of Sleep Medicine; *NREM*, non-rapid eye movement; *REM*, rapid eye movement; *R&K*, Rechtschaffen and Kales.

Normal sleep

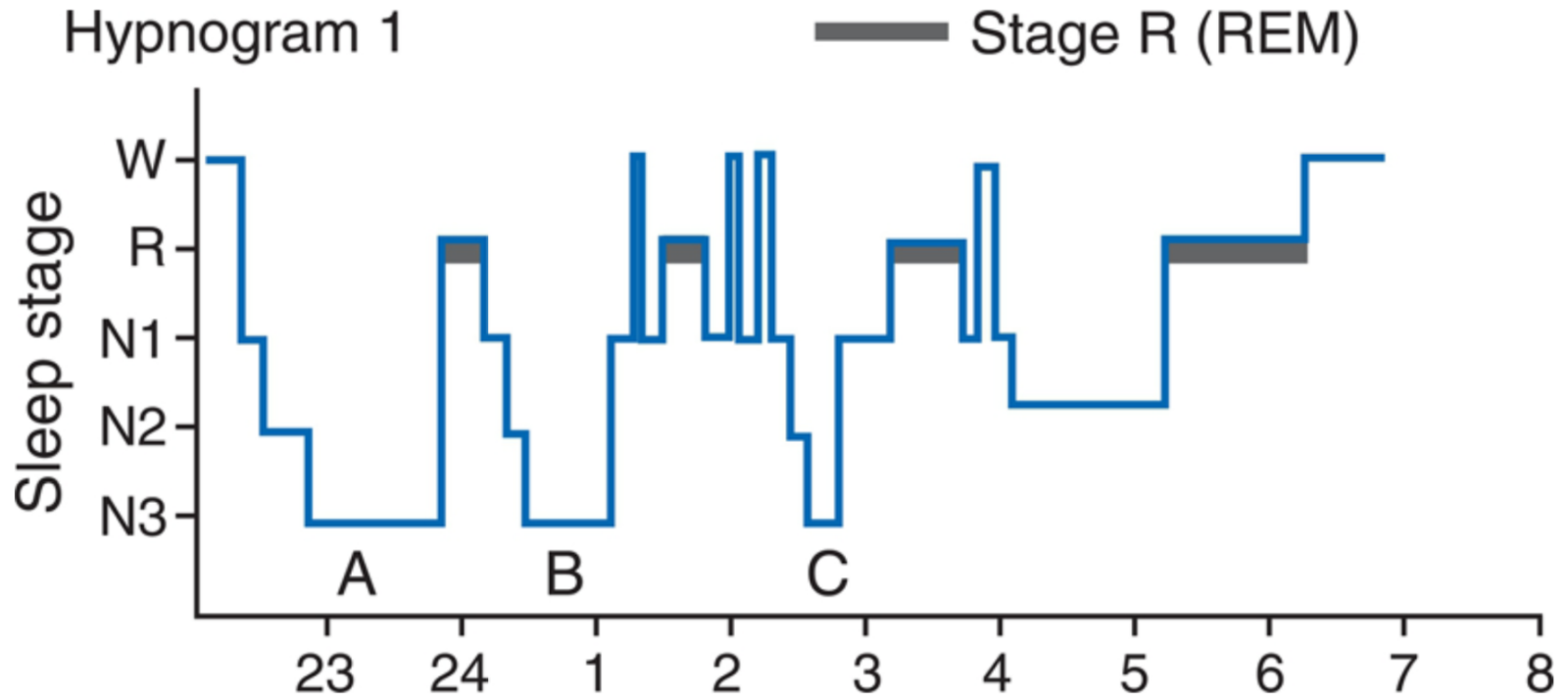


TABLE F1-2 Optimal Window Duration for Viewing Events in Polysomnography

Window Duration	Use
30 seconds (an epoch)	Sleep staging
60–120 seconds	Respiratory Events
15 seconds	Clinical EEG
10 seconds	ECG rhythms Identifying wave form frequency

ECG, Electrocardiography; *EEG*, electroencephalography.

Sleep Stage Characteristics

	EEG	EOG	Chin EMG
Stage W (eyes open)	Alpha + beta	REMs, blinks, reading EM	Relatively high
Stage W (eyes closed)	> 50% alpha	± SEMs	Variable
Stage N1	< 50% alpha > 50% LAMF	± SEMs	Variable, usually < wake
Stage N2	SS, KC*	None	Variable
Stage N3	SWA ≥ 20% (6 sec) SS may occur	None	Variable
Stage R	LAMF, no SS or KC	REMs*	Lowest of night

KC, K complex; *LAMF*, low amplitude mixed frequency; *REM*, rapid eye movement; *Reading EM*, reading eye movements; ±, may or may not be present; *SS*, sleep spindle; *SEM*, slow eye movement; *SWA*, slow wave activity.

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Wave Forms for Sleep Staging

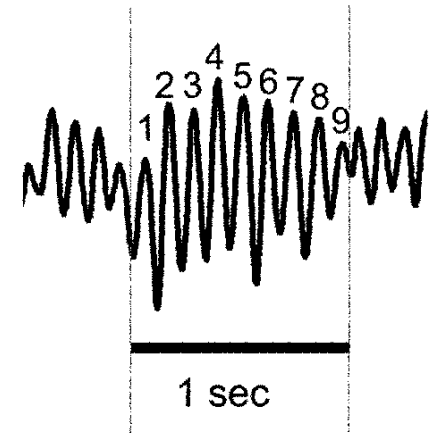
- **EEG activity**

- frequency in cycles per second (hertz [Hz])

- delta (0–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), & beta (> 13 Hz)

- amplitude (microvolts [μV])

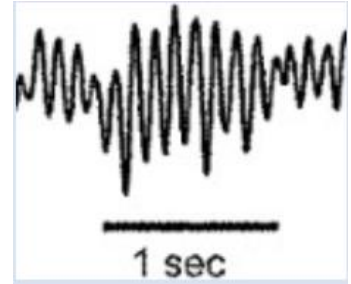
- shape





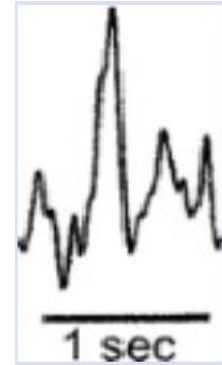
Alpha Activity (Alpha Rhythm)

- 8–13 hertz (Hz)
- Most prominent over the occipital areas
- Increased by eye closure & attenuated by eye opening
 - Characteristic EEG activity in **drowsy, eyes-closed stage W**
 - Common in **REM sleep** (1–2 Hz slower than during stage W)
 - May occur with arousals (brief awakenings)
 - 10% of persons do not produce alpha rhythm with eye closure



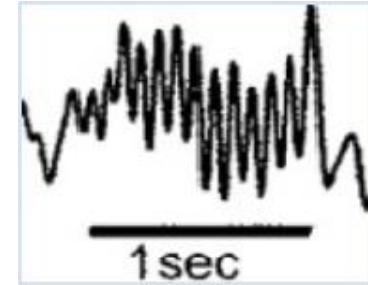
Vertex Sharp Wave

- Sharply contoured waves
- Maximal over the central region
 - derivations containing C3, C4, Cz
- distinguishable from the background activity
 - higher amplitude
- Duration < 0.5 sec
- Occurs in **stage N1** often near transition to stage N2
 - also in stage N2

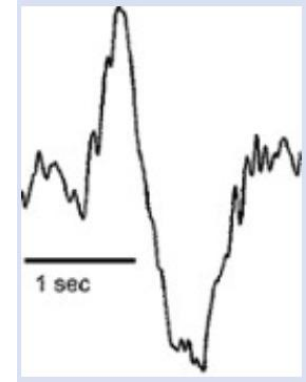


Sleep Spindle

- 11–16 Hz (classically 12–14 Hz)
- Maximal over central areas
- Duration ≥ 0.5 sec (0.5–1.5 sec)
- One of the defining characteristics of **stage N2**
 - May be seen in stage N3 sleep



K-complex (KC)

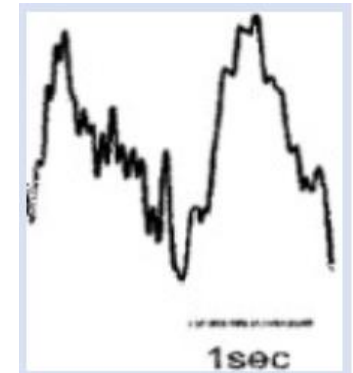


- High amplitude – biphasic deflection
 - A well-delineated negative sharp wave (upward) followed by a positive (downward) slow wave
- Maximal over frontal areas (frontal > central > occipital)
- Duration ≥ 0.5 sec
- Characteristic of **stage N2 sleep**

Slow Waves

(Slow Wave Activity [SWA])

- Frequency 0.5–2 Hz
- Amplitude > 75 microvolts (μV) peak-to-peak
- Frontal derivations
- Used to define stage N3 sleep
 - Stage N2 < 20% SWA (< 6 sec)
 - **Stage N3 \geq 20% SWA (\geq 6 sec)**



Sleep Stage Characteristics

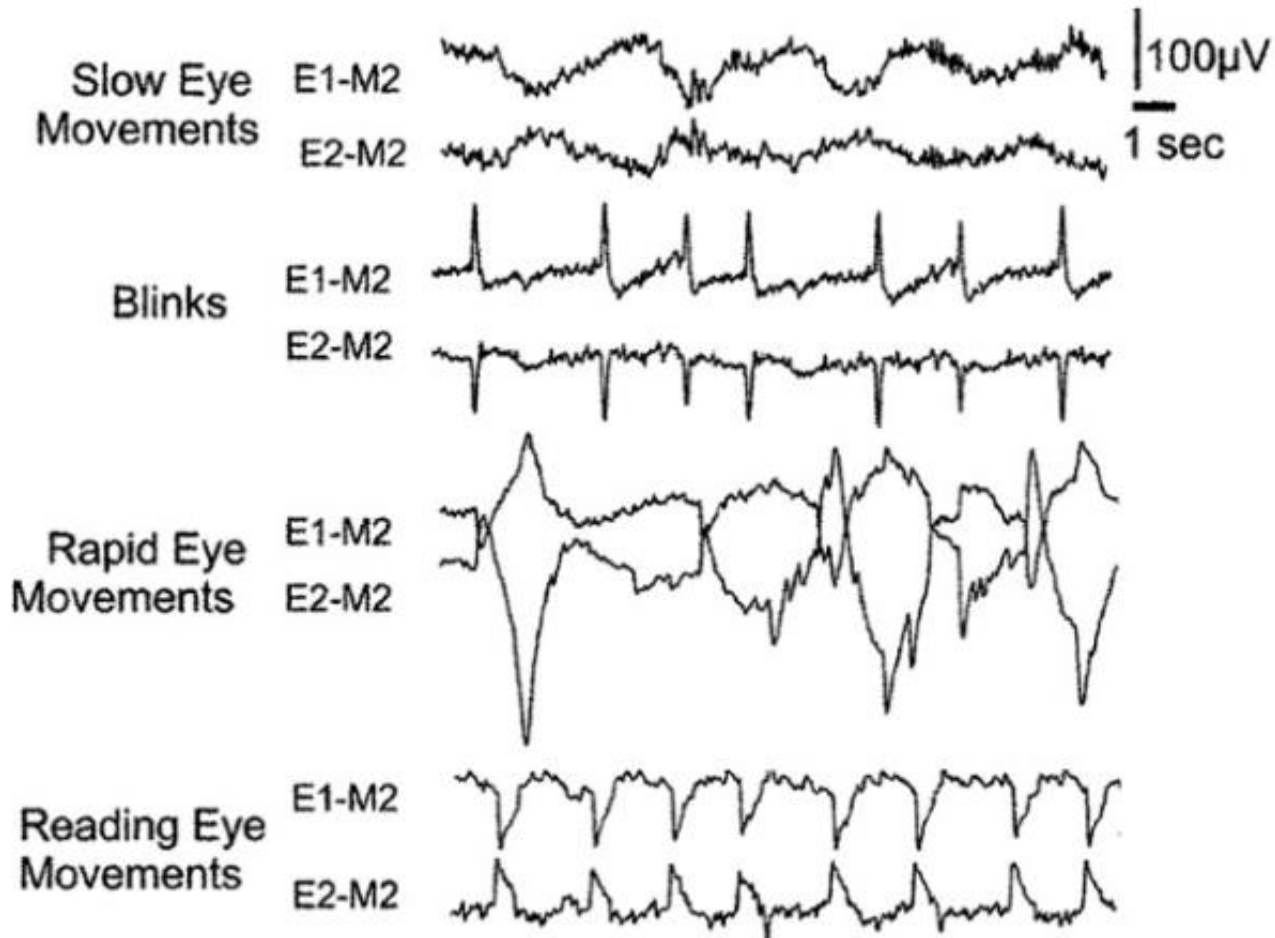
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KC, K complex; *LAMF*, low amplitude mixed frequency; *REM*, rapid eye movement; *Reading EM*, reading eye movements; ±, may or may not be present; *SS*, sleep spindle; *SEM*, slow eye movement; *SWA*, slow wave activity.

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Eye movement patterns



Eye movement patterns

- **Slow eye movements**
 - Conjugate, fairly regular, sinusoidal eye movements
 - With an initial deflection lasting > 500 msec

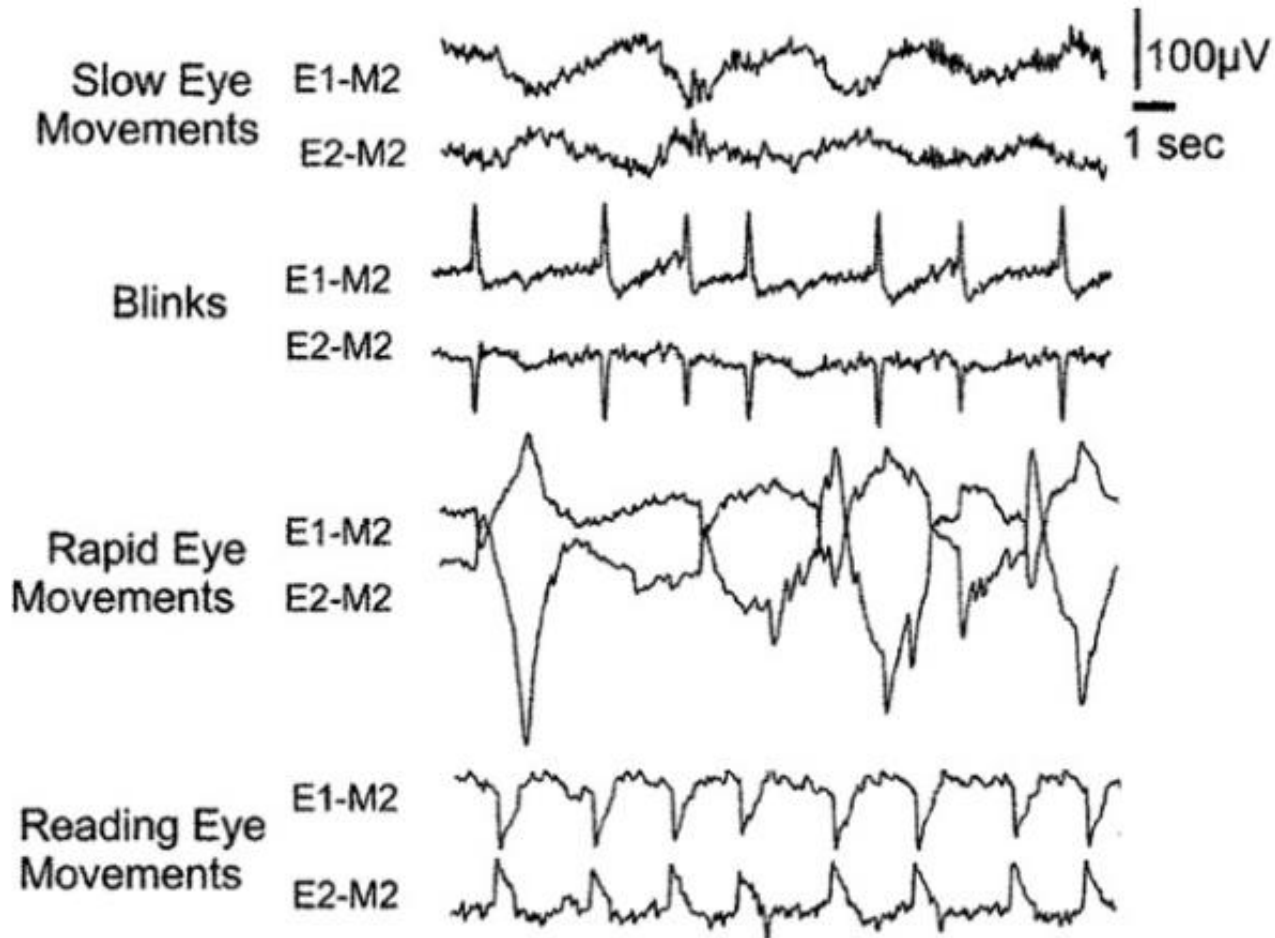
- **Eye blinks**
 - Conjugate vertical eye movements at a frequency of 0.5 to 2 Hz
 - Present in wakefulness with the eyes open or closed

Eye movement patterns

- **Rapid eye movements (REM)**
 - Conjugate, irregular, sharply peaked eye movements
 - With an initial deflection usually lasting < 500 msec

- **Reading eye movements**
 - Trains of conjugate eye movements
 - Consist of a slow phase followed by a rapid phase in the opposite direction as the subject reads

Eye movement patterns





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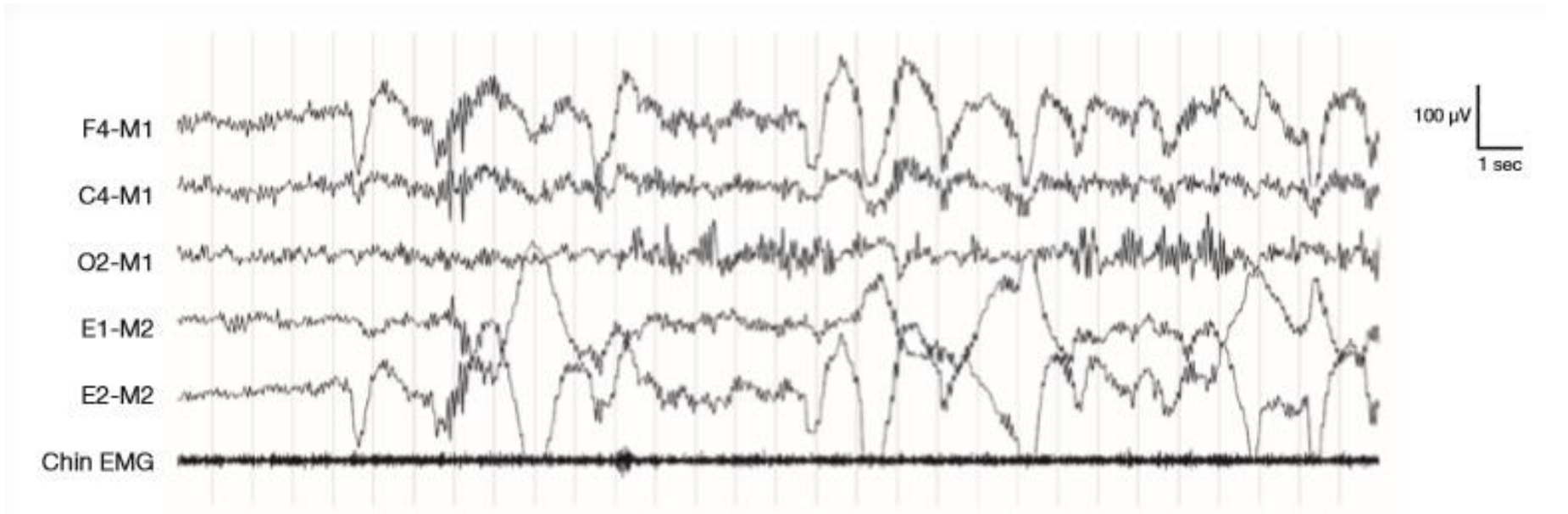
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Stage W Rules

- **More than 50% of the epoch contains EITHER (a) or (b) or BOTH:**
 - a. Alpha rhythm (posterior dominant rhythm) over the occipital region (individuals generating alpha rhythm with eye closure)
 - b. Other findings consistent with stage W (all individuals)
 - i. Eye blinks (0.5 to 2 Hz)
 - ii. Rapid eye movements associated with normal or high chin muscle tone
 - iii. Reading eye movements

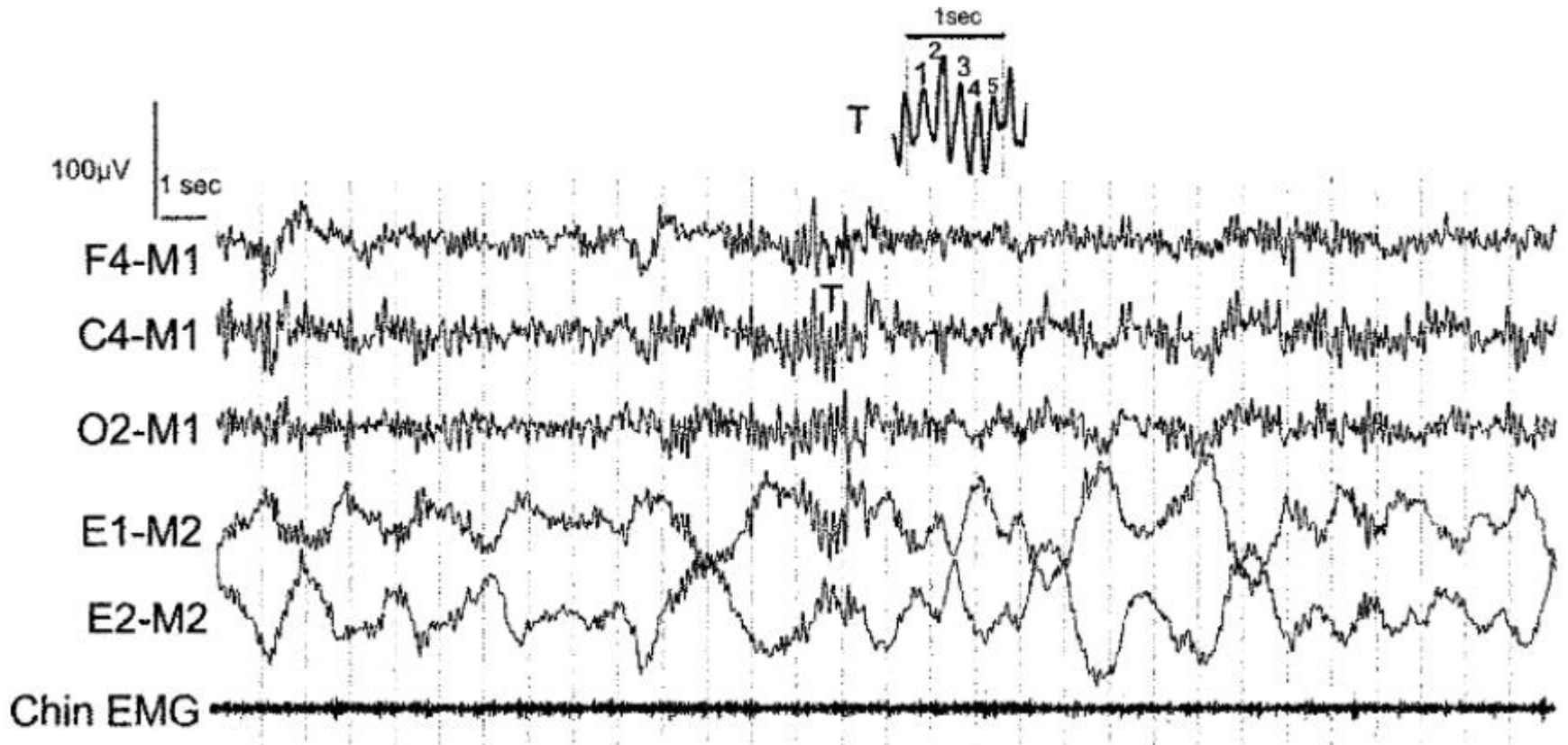
Stage W



Stage N1 Rules

- **In individuals who generate alpha rhythm**
 - If the alpha rhythm is attenuated & replaced by **LAMF activity (low-amplitude, mixed-frequency)** for more than 50% of the epoch
- **In individuals who do not generate alpha rhythm**
 - Commence with the earliest of ANY of the following phenomena:
 - EEG 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 N1



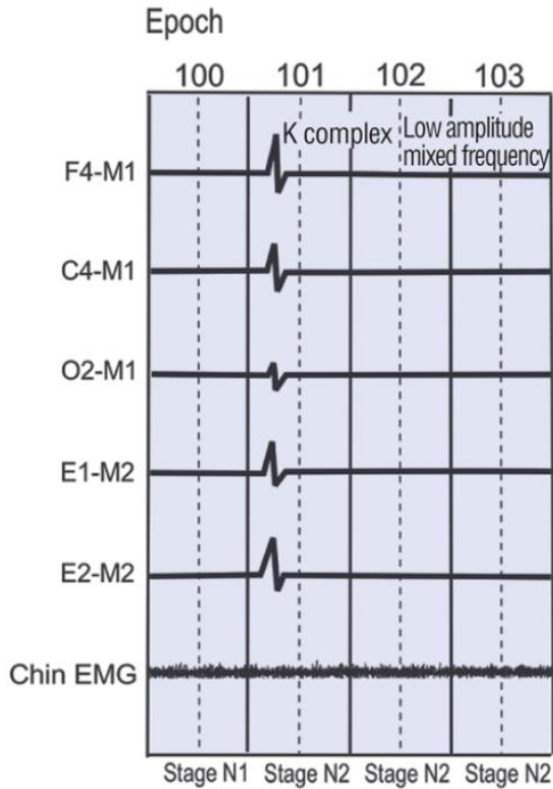
Stage N2 Rules

Start N2	Continue N2	Stop N2
KC-nonA or SS in first half of current epoch or last half of the previous epoch	EEG with LAMF without KC or SS If the epoch (or a group of epochs) is preceded by an epoch with a non-arousal KC or SS	Transition to stages W, N3, or R Arousal Major body movement followed by a slow eye movement

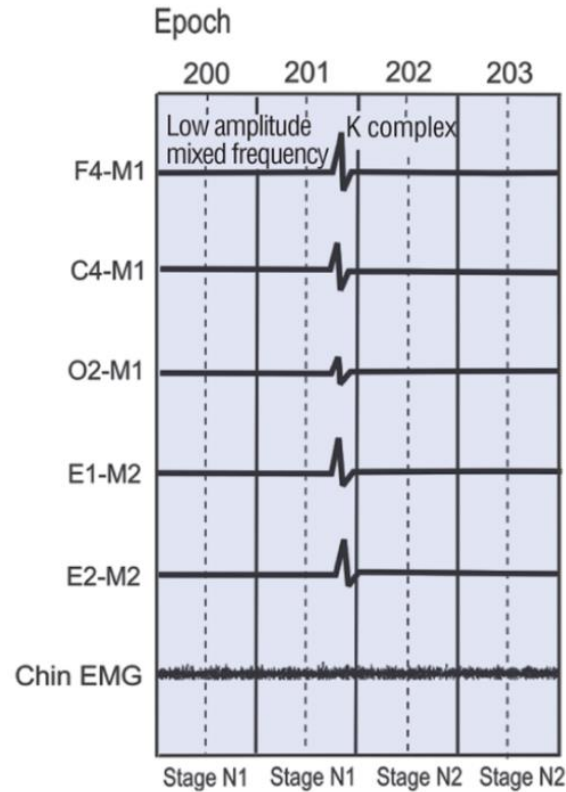
KC-nonA, K-complex not associated with arousal; *LAMF*, low-amplitude mixed-frequency; *SS*, sleep spindle.

Start stage N2

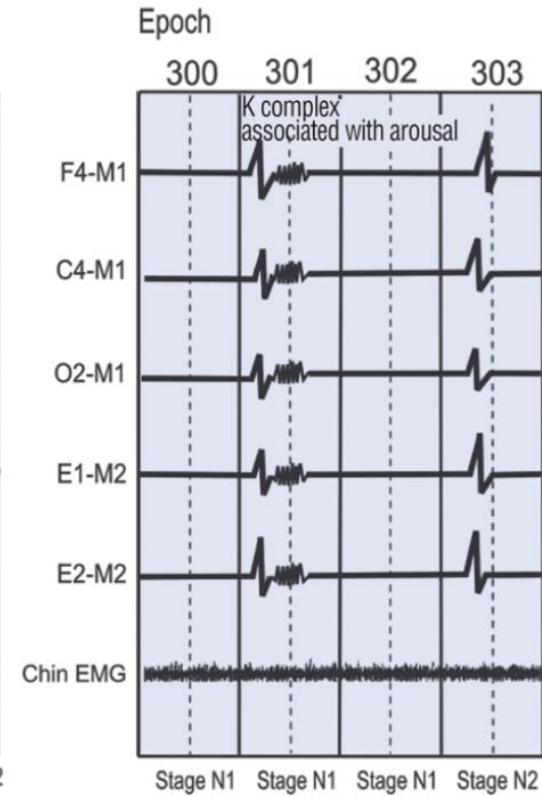
K complex first half of epoch



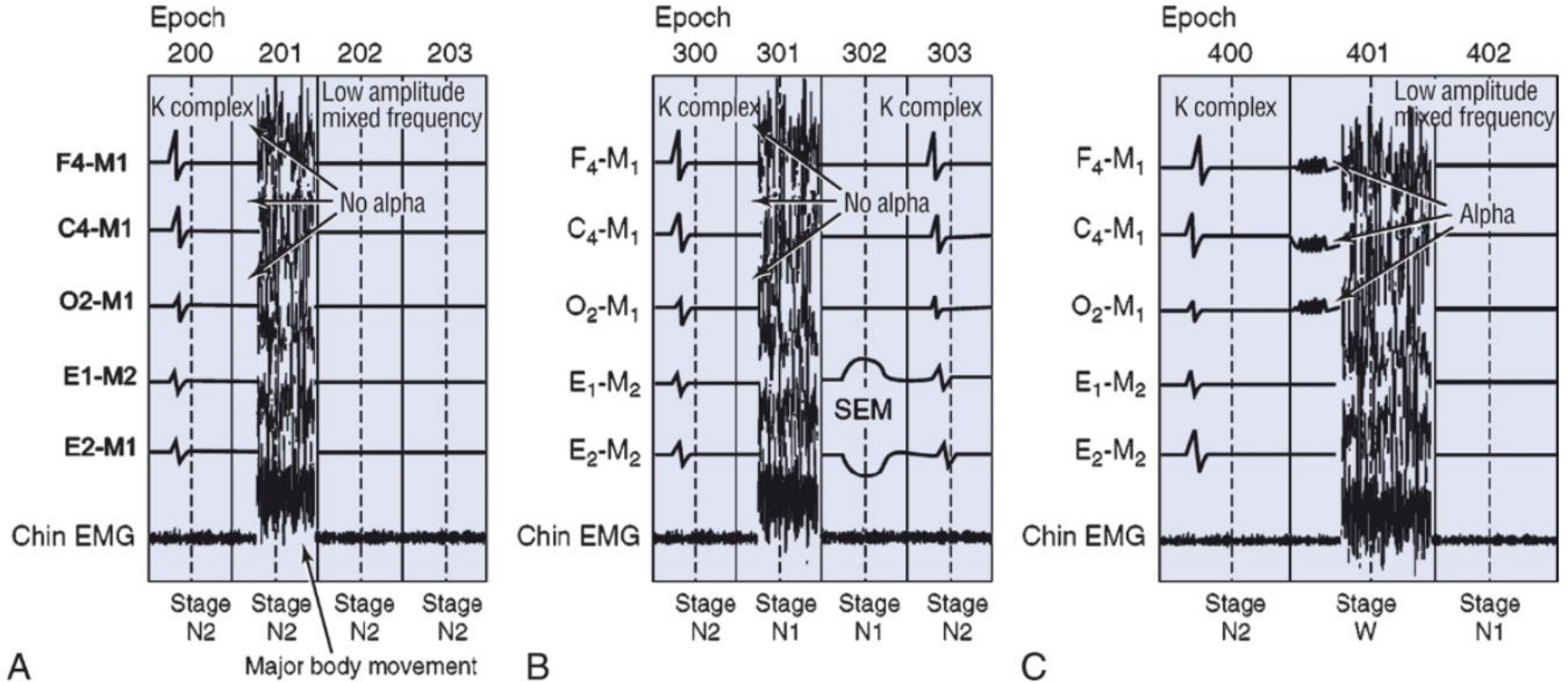
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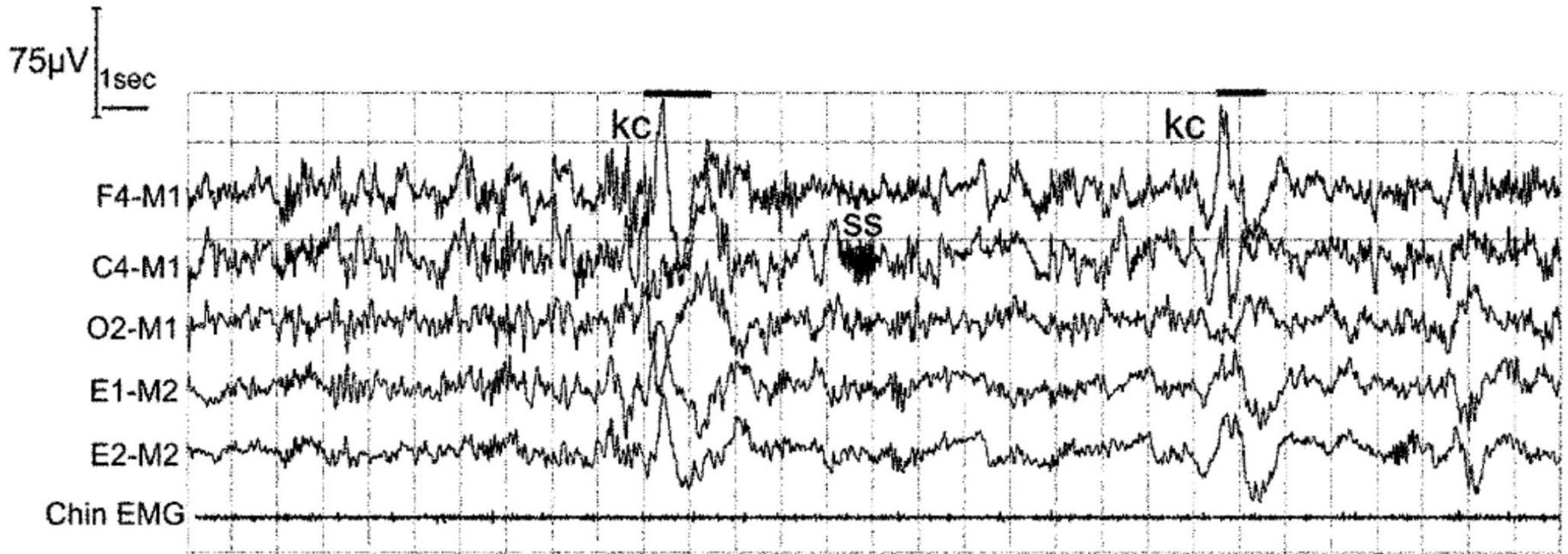
K complex associated with arousal not evidence for stage N2



Major Body Movement interrupts stage N2



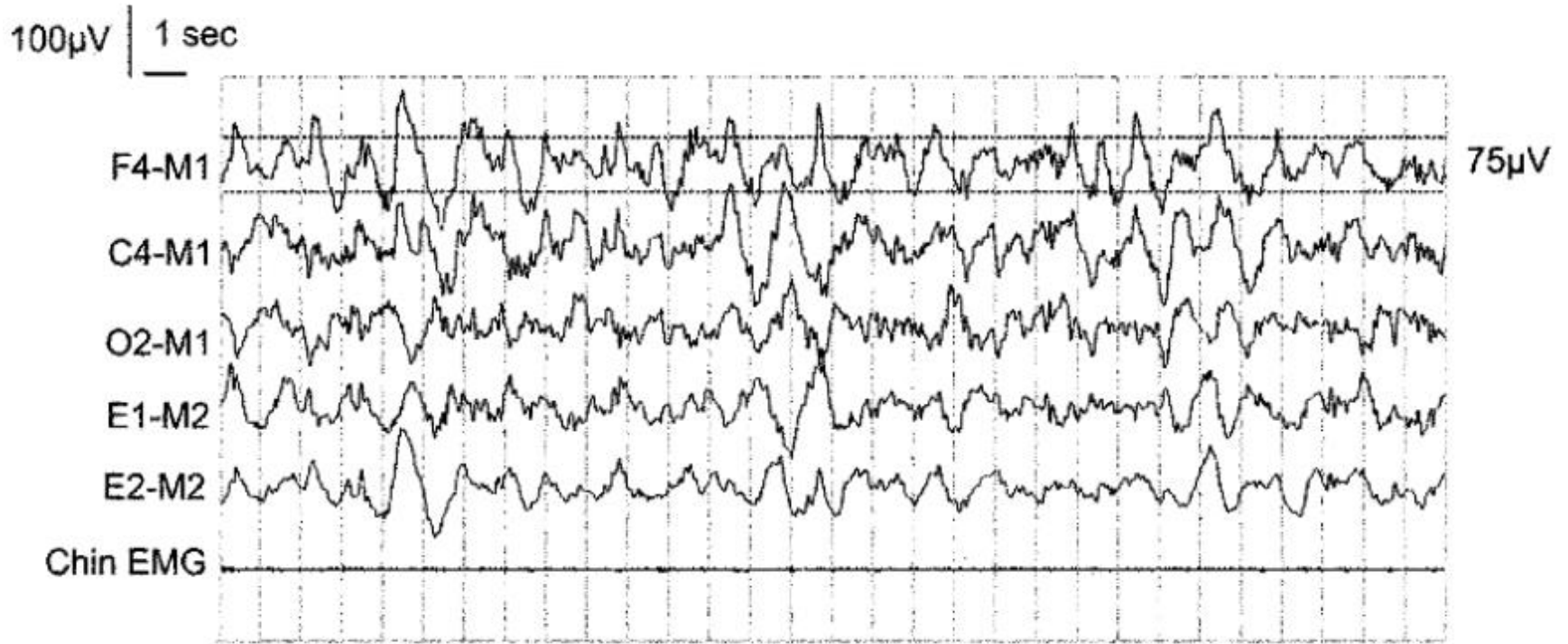
Stage N2



Stage N3 Rules

- **20% or more** of an epoch consists of **slow wave activity**, irrespective of age. (*20% of 30 second epoch = 6 seconds*)
 - EEG: SWA \geq 20% of the epoch (> 6 seconds),
sleep spindles may be present in stage N3
 - EOG: Eye movements are not typically seen during stage N3
 - EMG: chin EMG is of variable amplitude, often lower than in stage N2 sleep & sometimes as low as in stage R sleep

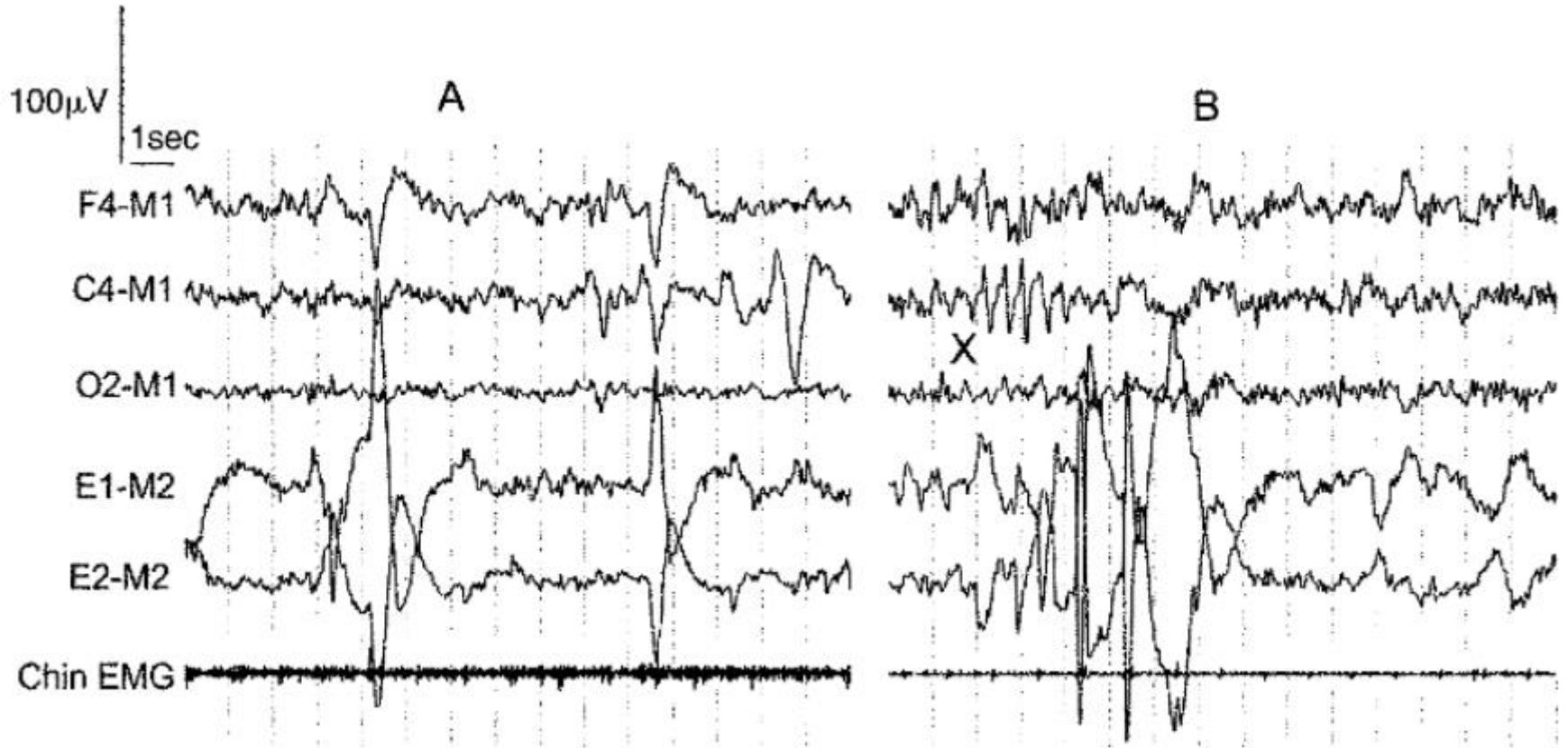
Stage N3



Stage R Rules

- Definite stage R
 - epochs with ALL of the following phenomena
 - LAMF EEG activity without K-complexes or sleep spindles
 - Low chin EMG tone for the majority of the epoch & concurrent with REMs
 - REMs at any position within the epoch

Stage R



Stage R Rules

- Begin & Continue scoring stage R
 - preceding & contiguous with an epoch of definite stage R in the *absence of REMs*, if all of the following are present
 - EEG : LAMF activity without K-complexes or sleep spindles
 - Chin EMG tone : low (at the stage R level)
 - No intervening arousal is present
 - SEMs following an arousal or stage W are absent

Stage R Rules

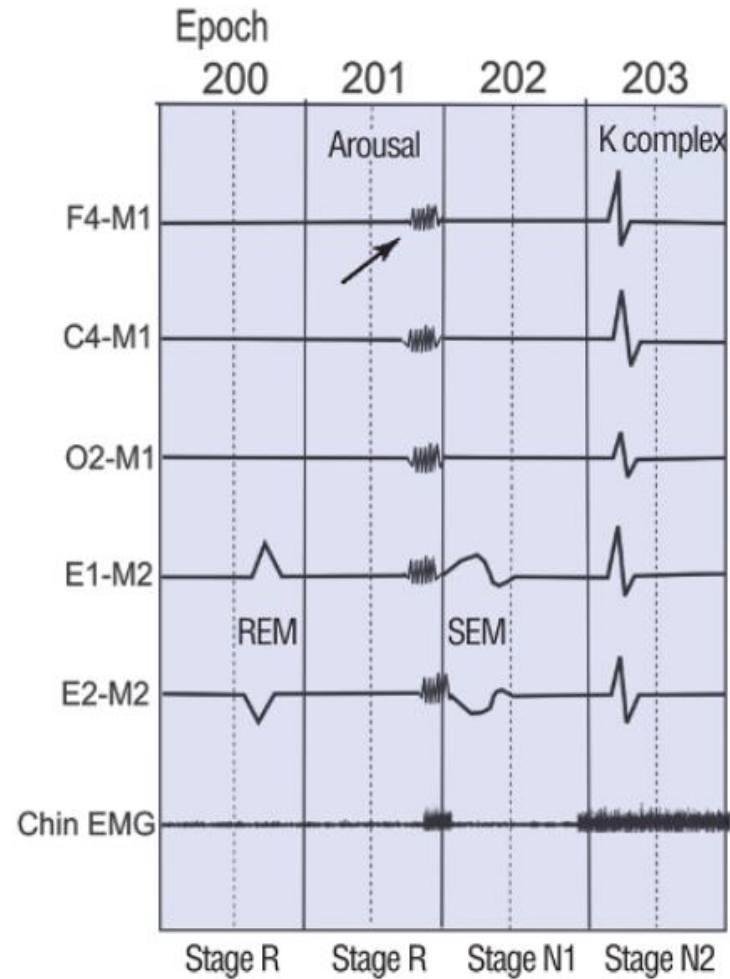
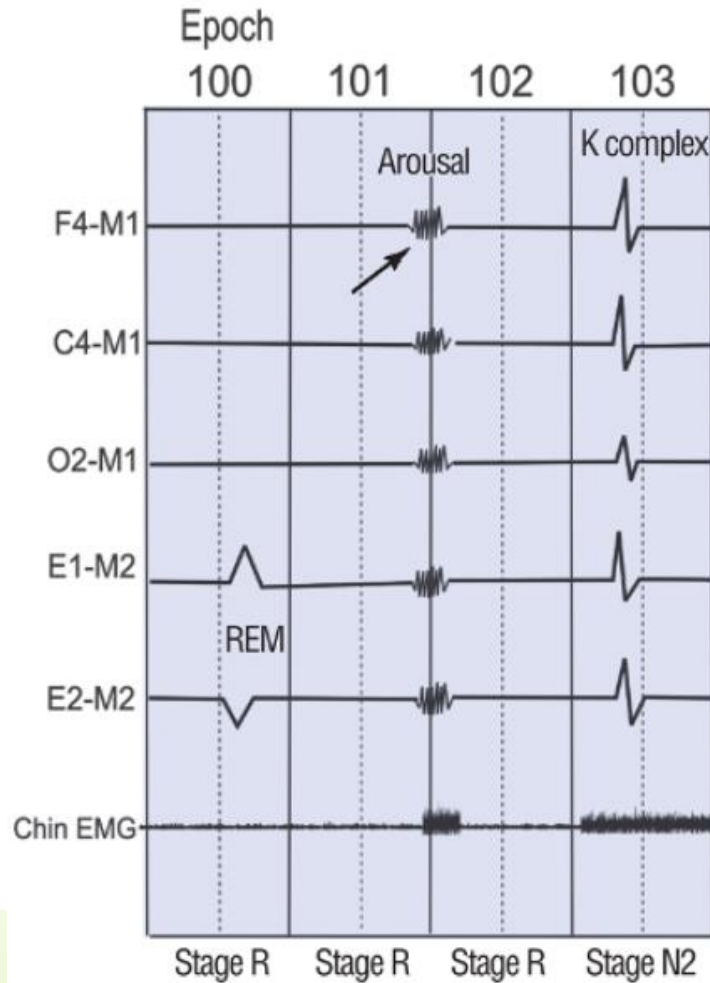
- End scoring stage R
when ONE OR MORE of the following occur:
 - 1) Transition to stage W or N3 has occurred.
 - 2) An increase in chin EMG tone above the level of stage R seen for the majority of the epoch & criteria for stage N1 are met.

Stage R Rules

3) Arousal occurs & followed by LAMF EEG & EMG tone remains low.

- If SEMs follow the arousal, score the segment containing them as stage N1, & continue to score stage N1 until evidence for another stage of sleep is present.
- If no SEMs follow the arousal & chin EMG tone remains low, continue to score as stage R.

Stage R & Arousal





Stage R Rules

4) A major body movement followed by SEMs & LAMF EEG without K-complexes (KCs) or sleep spindles (SS), score stage N1 until evidence for another sleep stage.

- If no SEMs are present, & chin tone remains low, continue to score stage R

5) One or more K complexes or sleep spindles are present in the first half of the epoch in the absence of REM, even if chin EMG tone remains low.

→ Score the epoch as stage N2

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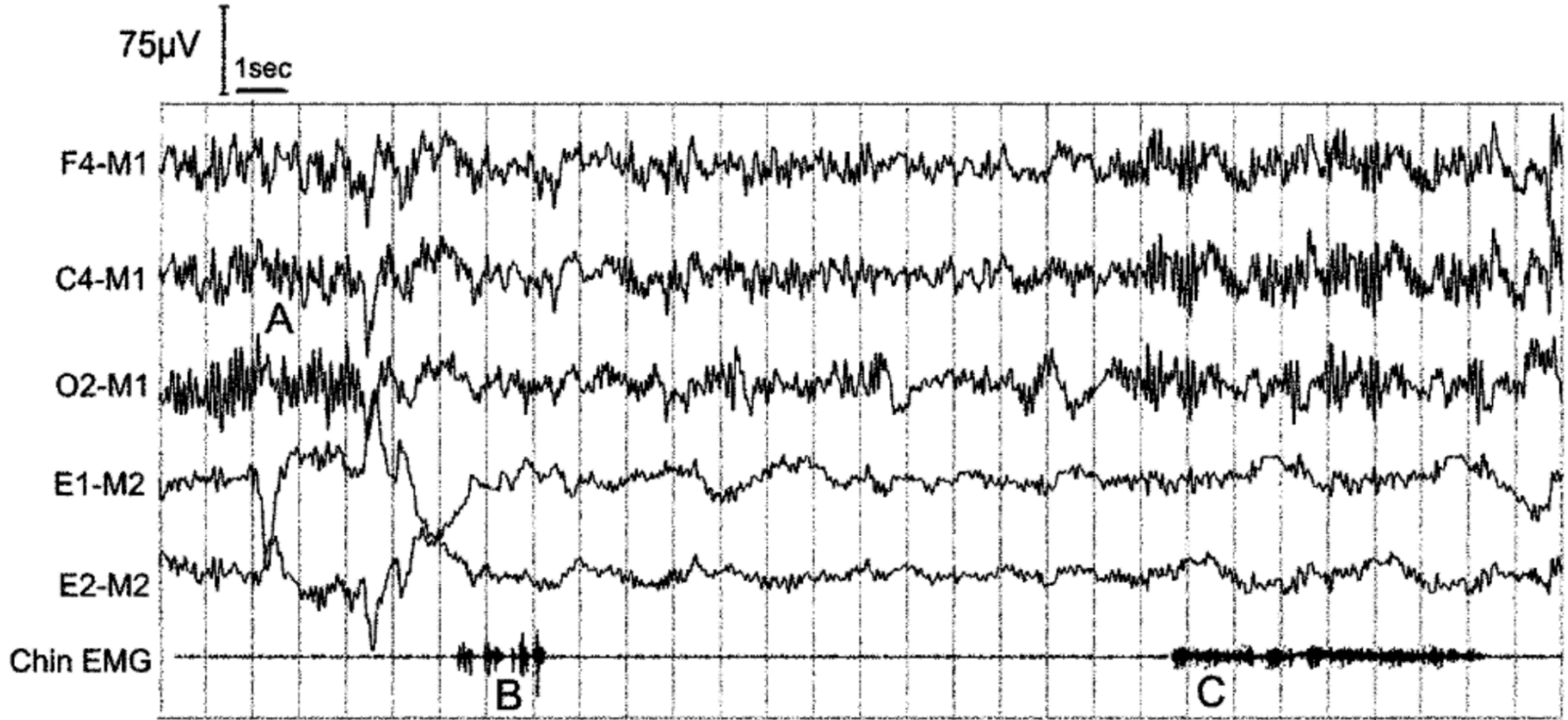
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Arousal

- Transient phenomena that may lead to wakefulness or only briefly interrupt sleep
 - frequent arousals → daytime sleepiness
- Arousal Rules
 - an abrupt shift of EEG frequency
 - 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
 - During REM
 - Requires a concurrent increase in submental EMG lasting at least 1 sec

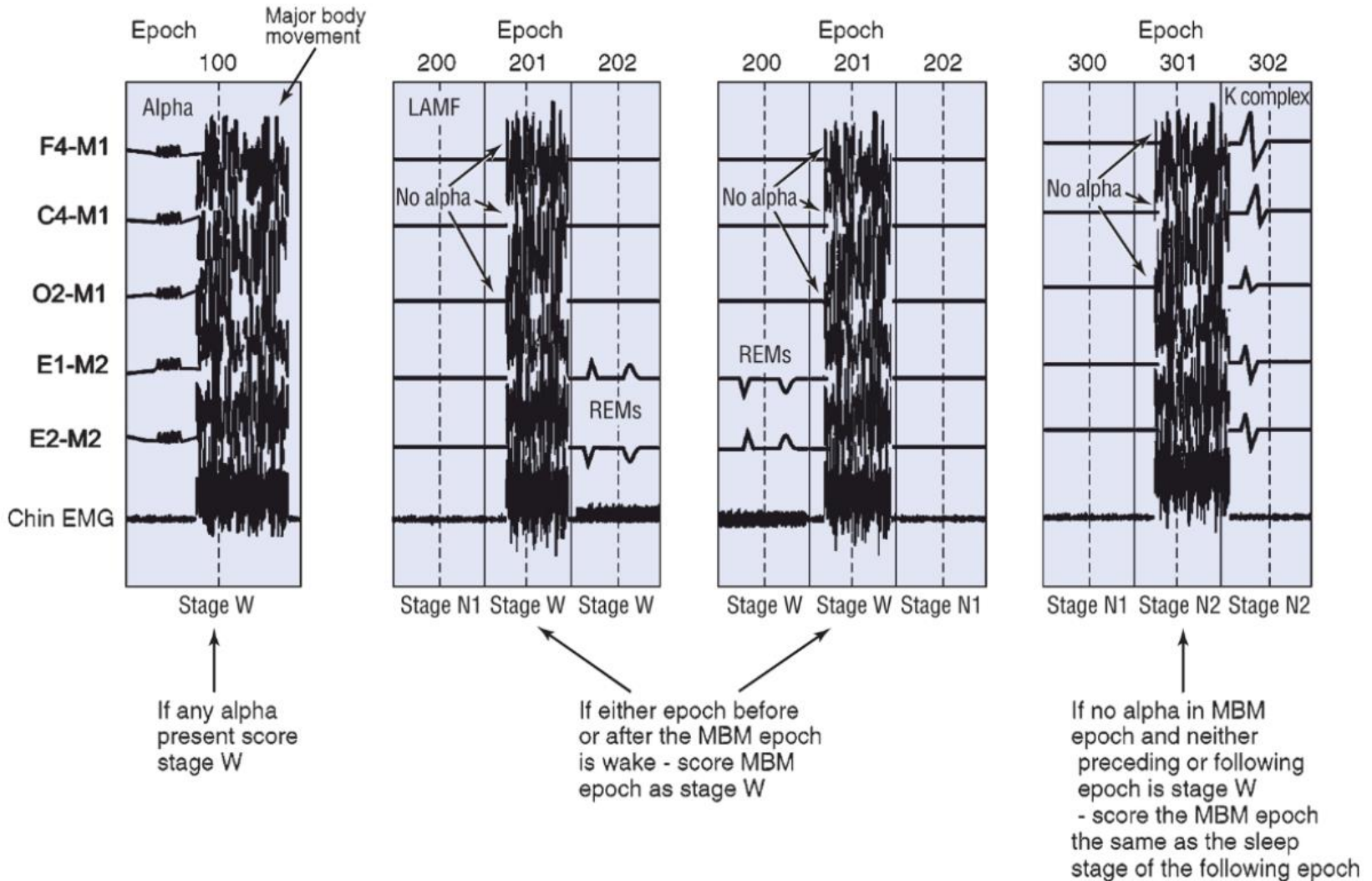
Arousal



Major Body Movements

- movement & muscle artifact obscuring the EEG for more than half an epoch to the extent that the sleep stage cannot be determined
- Scoring Rules
 - Score stage W
 - if alpha rhythm is present for part of the epoch (even if < 15 secs in duration)
 - Score stage W in the absence of alpha rhythm
 - if an epoch scorable as stage W either precedes or follows the epoch with MBM
 - If neither A or B apply, score an epoch with a MBM as the same stage as the epoch that follows it

SCORING MAJOR BODY MOVEMENT (MBM) EPOCHS



Summary

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Reference

- Richard B. Berry & Mary H. Wagner, SLEEP MEDICINE PEARLS, 3rd ed. 2015
- The AASM Manual for the Scoring of Sleep and Associated Events

경청해주셔서 감사합니다.

