Pediatric Scoring

Visual Rules

- When do pediatric rules apply?
  - Pediatric sleep scoring rules can be used to score sleep and wake in children 2 months post-term or older

- Electrode placement for pediatrics
  - Chin EMG often needs to be reduced from 2 cm to 1 cm
  - Distance from the eyes in EOG electrodes often needs to be reduced from 1 cm to 0.5 cm in infants and children with small heads

Staging Rules for Infants

- Used for ages 0-2 months post-term (37-48 weeks postmenstrual age)
  - Post menstrual age (PMA) is gestational age at birth + # of weeks postpartum
  - Gestational age (GA) is time elapsed between 1st day of mother's last menstrual period & day of delivery
    - If pregnancy due to assisted reproductive technology, GA is calculated by adding 2 weeks to PMA
  - Chronological age (postnatal or legal age) = Time since birth
  - Knowing infant's post menstrual age crucial for interpreting normalcy, immaturity, or abnormality of EEG/PSG
- Infant classifications
  - Pre-term = <37 weeks gestation
  - Full-term = 37-44 weeks
  - Post-term = >44 weeks
  - Neonate = First 28 days after birth
  - Infant = 1-12 months of age

Staging Rules for Infants

- Sleep stages 0–2 months post-term (37–48 weeks PMA):
  - Stage W = Wakefulness
  - Stage N = NREM
  - Stage R = REM
  - Stage T = Transitional
- Recommended scoring rules:
  - Score stages in 30-second, sequential epochs from beginning
  - Assign stage to each epoch
  - If ≥2 stages coexist, select the stage comprising the greatest amount
  - If ≥2 PSG characteristics are conflicting for stage R or stage N, score the epoch as stage T
  - Score sleep onset as 1st epoch of sleep

Staging Rules for Infants

- Sleep and wakefulness in infants 38–48 weeks PMA are scored based on:
  - Behavioral observation
  - Regularity/irregularity of respiration
  - EEG, EOG, and chin EMG patterns
- Score sleep based on the behavioral characteristics on slide 6
- Score sleep based on the respiration characteristics on slide 7
- Score sleep based on the EEG characteristics on slides 8–9

Behavioral Characteristics of Sleep Stages in Infants

Stages	Behavioral Characteristics
Wake	Calm or active with eyes open, scanning eye movements, and brief eye closure can occur with crying
N	Eyes closed, few movements, sucking can occur
R	Eyes closed, REM seen under closed eyelids, squirming, sucking, grimacing, small movements of face or limbs

Respiration Characteristics of Sleep Stages in Infants

Stages	Respiration Characteristics
Wake	Irregular, rapid, and shallow
N	Regular
R	Irregular, some central pauses (may or may not meet criteria for apnea)

EEG Characteristics of Sleep Stages in Infants

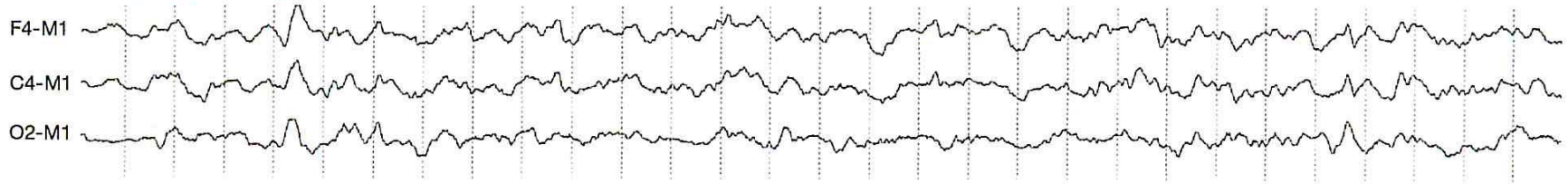
Patterns	EEG Characteristics	Stages
Discontinuous		
Trace alternant (TA)	In full-term infants, generally seen in stage N. Characterized by at least 3 alternating runs of bilaterally symmetrical synchronous high voltage (50-150 uV) bursts of 1-3 Hz delta activity lasting 5-6 seconds (range 3-8 seconds) alternating with periods of lower amplitude (25-50 uV) 4-7 Hz theta activity (range 4-12 seconds)	N

EEG Characteristics of Sleep Stages in Infants

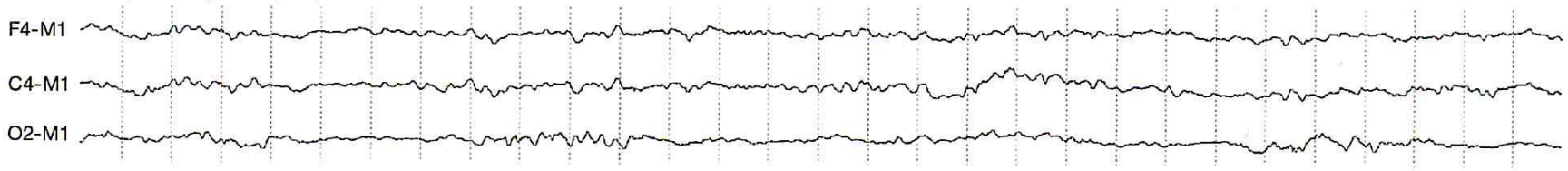
Patterns	EEG Characteristics	Stages
Continuous		
Low voltage irregular (LVI)	Continuous LAMF activity with delta and predominantly theta activity	R, W
High voltage slow (HVS)	Continuous synchronous symmetrical predominantly high voltage 1–3 Hz delta activity	N, rarely R
Mixed (M)	Both high voltage slow and low voltage polyrhythmic components intermingled with little periodicity. Amplitude lower than HVS.	W, R, rarely N
Waveforms of Interest		
Sleep spindles	12–14 Hz, asynchronous, most prominent in Cz and central derivations. Occur only in stage N.	N

Infant EEG Characteristics

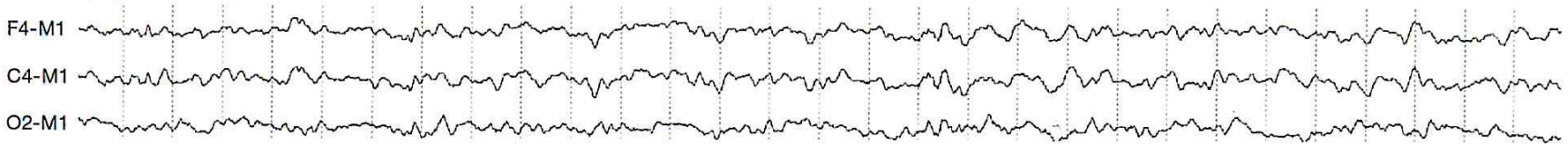
High voltage slow (HVS)



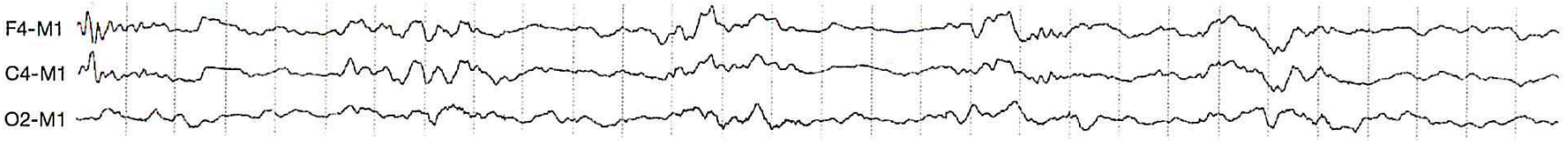
Low voltage irregular (LVI)



Mixed (M)



Trace alternant (TA)



Staging Rules for Infants

- Score sleep based on the EOG and chin EMG characteristics on slide 12

EOG and EMG Characteristics of Sleep Stages in Infants

Stages	EOG Characteristics

Stages	Chin EMG Patterns
Wake	Present, movement artifact
N	Present; could be lower than wake
R	Low, transient muscle activity may occur

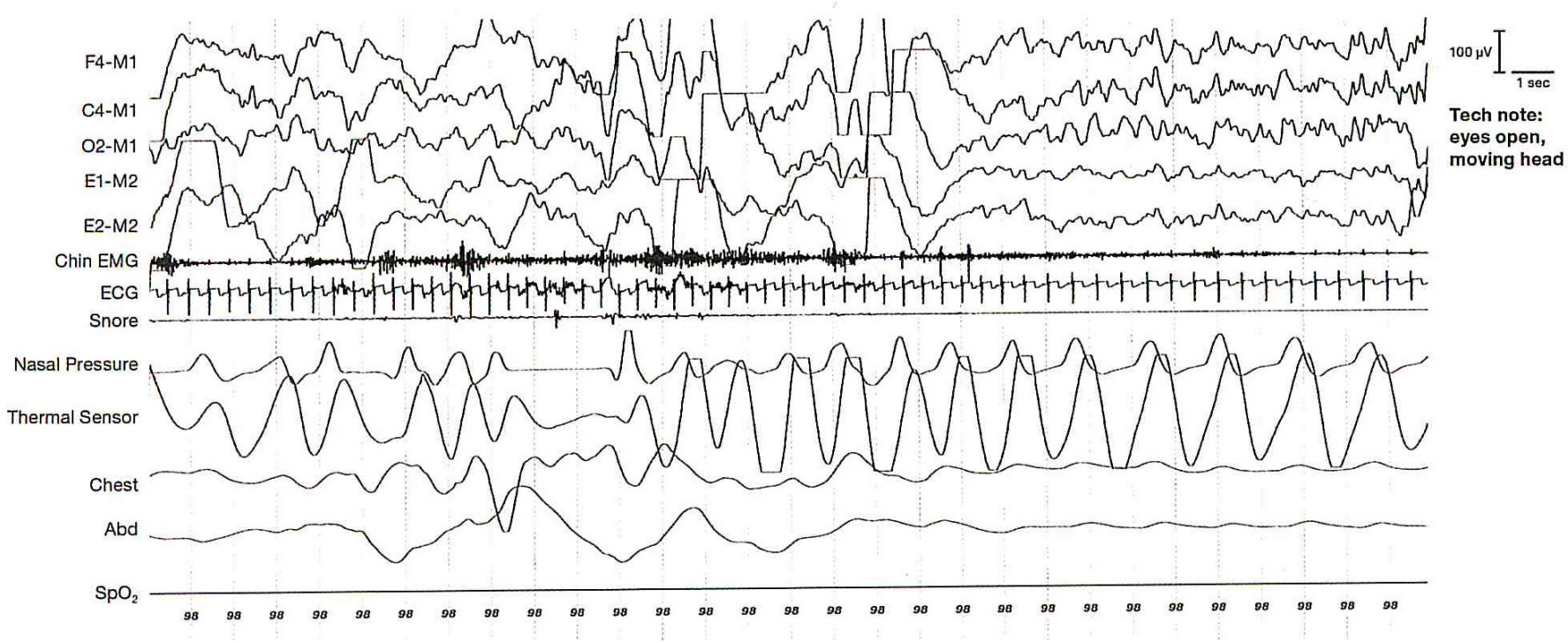
Summary of Characteristics of Sleep Stages in Infants

Stages	Behavioral	Respiration	EEG	EOG	Chin EMG
Wake	Eyes open, crying, feeding	Irregular	LVI or M	REMs, blinks, scanning eye movements	Present
N	Reduced movement relative to wake (eyes closed, periodic sucking, occasional startle)	Regular	TA, HVS, sleep spindles, or M	Eyes closed with no eye movements	Present or low
R	Eyes closed, small movements	Irregular	LVI or M (rarely HVS)	REMs or eyes closed with no eye movements	Low, transient muscle activity may occur

Stage W in Infants

- Wake
  - Calm or active with eyes open
  - Scanning eye movements
  - Brief transient eye closure can occur with crying
  - Irregular, rapid, and shallow respirations
  - Low voltage, irregular EEG
  - Eye blinks
  - REMs
  - Scanning eye movements
  - Movement artifact in chin EMG
- Score Wake if any of the following present for majority of epoch:
  - Eyes wide open or open intermittently
  - Vocalization or actively feeding
  - REMs or scanning eye movements
  - Sustained chin EMG tone with bursts of muscle activity
  - Irregular respiration
  - Low voltage, irregular or mixed EEG

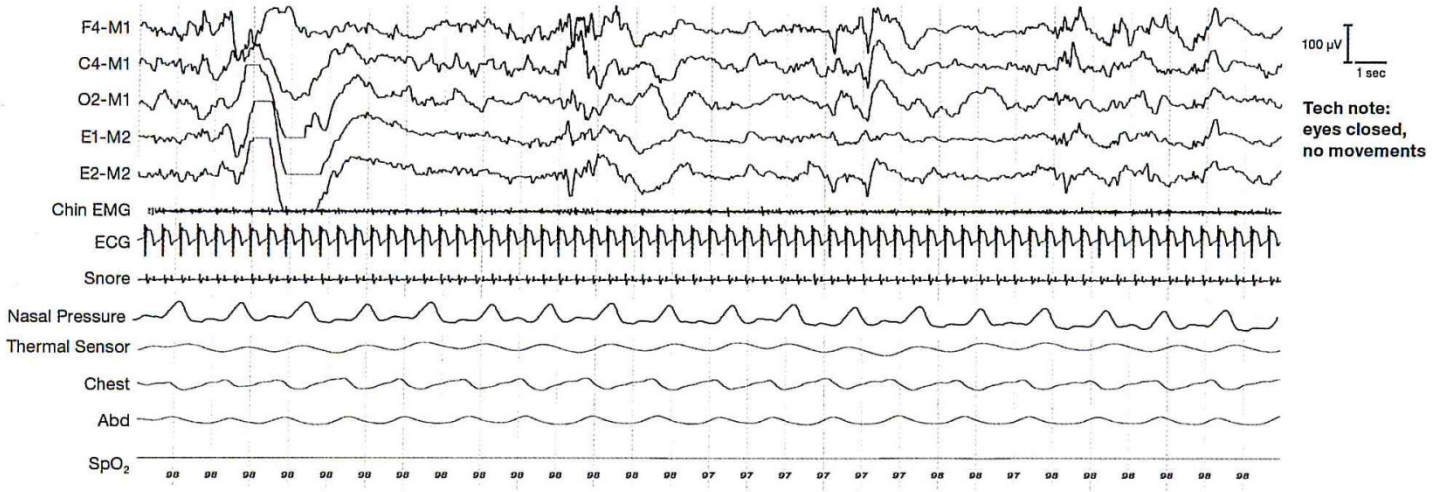
Stage W in Infants

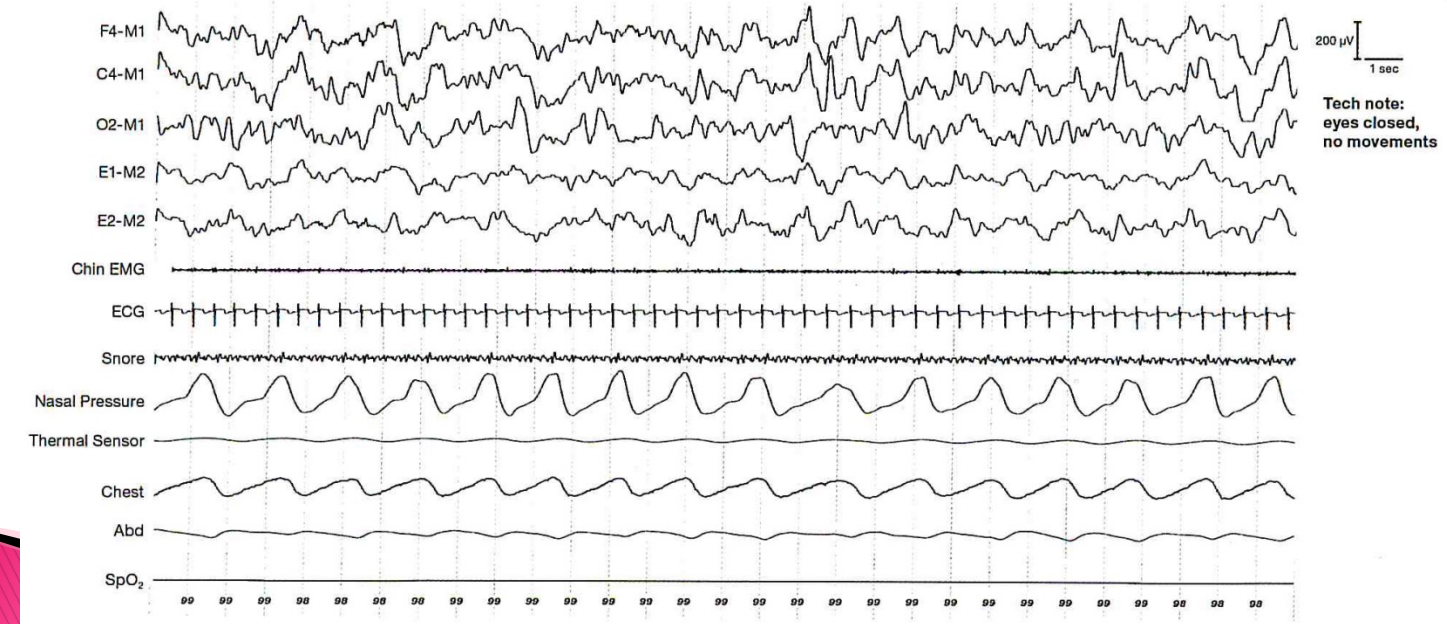


Staging Rules for Infants

- Stage N
  - Eyes closed, not moving
  - Few movements
  - Periodic sucking can occur
  - Occasional startle
  - Regular respiration
  - Trace alternant EEG pattern
    - At least 3 alternating runs of bilaterally symmetrical synchronous high voltage (50–150 uV) bursts of 1–3 Hz delta activity lasting 5–6 seconds (range 3–8 seconds) alternating with periods of lower amplitude (25–50 uV) 4–7 Hz theta activity (range 4–12 seconds)
  - High voltage slow (HVS): 1–3 Hz
  - Sleep spindles (12–14 Hz)
  - Lower than wake chin EMG

Stage N in Infants



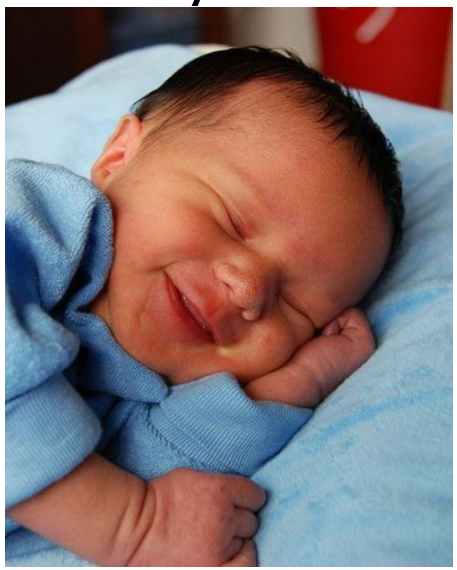


Stage N Scoring Rules for Infants

- Score stage N if 4 or more of the following are present for the majority of the epoch:
  - Eyes closed with no eye movements
  - Chin EMG tone present
  - Regular respiration
  - Trace alternant, high voltage slow, or sleep spindles present
  - Reduced movement relative to wake

Stage R for Infants

- Stage R
  - Eyes closed with REM seen under closed eyelids
  - Squirming
  - Sucking
  - Grimacing
  - Small movements of face or limbs
  - Irregular respiration
    - Some central pauses
  - Low voltage, irregular EEG
  - Low chin EMG
  - Transient muscle activity may occur



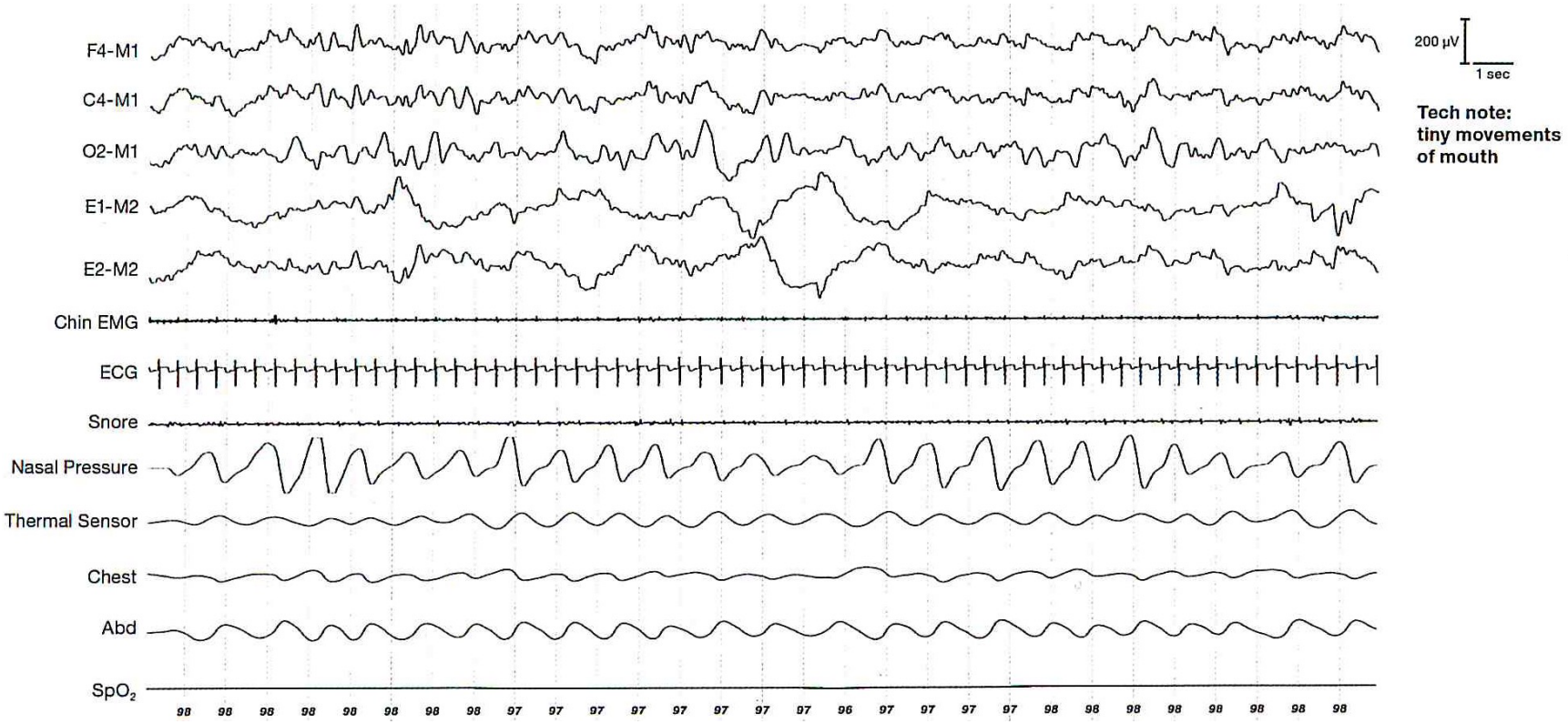
Stage R for Infants

- Score stage R (definite R) in epochs with 4 or more of the following present, including irregular respiration AND REMs:
  - Low chin EMG (for majority of epoch)
  - Eyes closed with at least one REM (concurrent with low chin tone)
  - Irregular respiration
  - Mouthing, sucking, twitches, or brief head movements
  - EEG exhibits a continuous pattern without sleep spindles

Stage R for Infants

- Score segments of sleep contiguous with and following an epoch of definite R in the absence of REMs as stage R if ALL the following are present:
  - EEG shows low or medium amplitude mixed-frequency activity without trace alternant or sleep spindles
  - Chin muscle tone is low for majority of the epoch
  - No intervening arousal

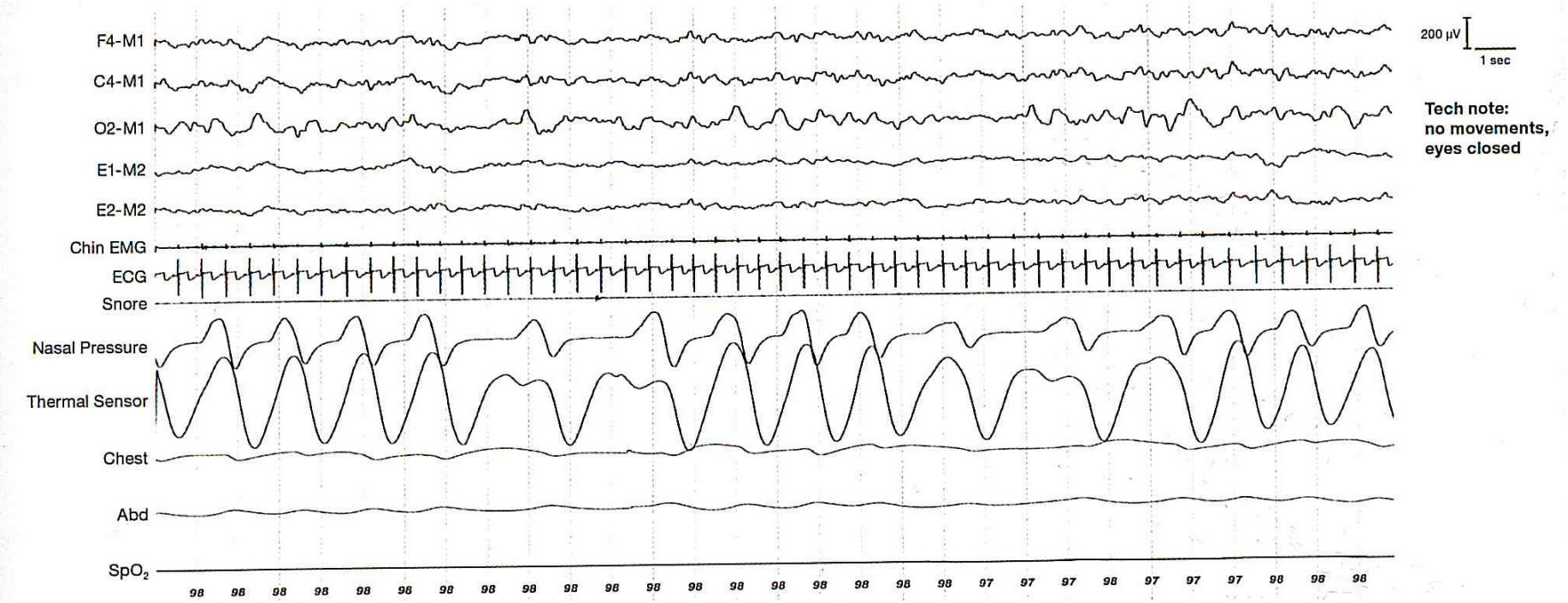
Stage R in Infants



Stage T for Infants

- Stage T
  - Scored when 3 NREM and 2 REM --or-- 2 NREM and 3 REM characteristics are present
- Score an epoch as stage N, stage R, or stage W if only one PSG characteristic is discordant for the sleep state
- Transitional (T) or indeterminate sleep is common in infants because of discordant features (has more than one sleep state represented)
  - Most often occurs in transitions from stage W to stage R sleep, before awakening, and at sleep onset

Stage T in Infants



Staging Notes for Infants

- Stage N = "Quiet Sleep"
- Stage R = "Active Sleep"
- Stage T = "Indeterminate Sleep"
- Up until 2-3 months post-term, the 1st epoch of sleep in infants is often Stage R
- Transition to sleep is characterized by relative immobility, absence of focused attention, and intermittent eye closure
  - If eyes closed > 3 minutes, considered asleep
- Regularity/irregularity of respiration during sleep is most reliable PSG characteristic in differentiating Stage N and Stage R

Staging Notes for Infants

- Periodic breathing is common during Stage R and may rarely occur during Stage N in normal infants
- Pathological EEG waveforms, such as those from spike and slow wave, projected rhythms, or those generated due to underlying pathology, should not be included in defining stage or state
- Trace alternant 1st appears at 37 weeks PMA, is the predominant EEG pattern in Stage N at 40 weeks PMA, and unlikely to be seen after 44 weeks PMA (replaced by HVS activity)
- HVS activity is more mature EEG pattern of Stage N at term
  - Characterized by continuous synchronous symmetrical 100-150 uV 1-3 Hz delta activity (prominent in occipital or central region)

Staging Notes for Infants

- Scanning eye movements can be seen as early as 2 weeks post-term
- Stage T is scored when 3 NREM and 2 REM or 2 NREM and 3 REM characteristics are present
- Epochs of sleep contiguous with and following an epoch of definite stage R should be scored as stage R

Technical Note for Infants

- Since behavioral patterns are extremely useful, synchronized video and audio recording is highly desirable.

General Scoring of Sleep Stages in Infants

- Non-EEG correlates for recognizing REM vs. NREM in infants younger than 6 months
  - REM
    - Irregular respiration
    - Chin EMG atonia
    - Transient muscle activity (muscle twitches)
    - Rapid eye movements
  - NREM
    - Regular respiration
    - Absence of eye movements
    - Preserved chin EMG tone

General Scoring of Sleep Stages in Pediatrics

- Stages (2 months post-term or older):
  - Stage W = Wakefulness
  - Stage N1 = NREM 1
  - Stage N2 = NREM 2
  - Stage N3 = NREM 3
  - Stage N = NREM
  - Stage R = REM

General Scoring of Sleep Stages in Pediatrics

- Dependent of development
  - Usually by 5-6 months post-term and occasionally in infants as young as 4 months post-term, sleep meets criteria for individual sleep stages

- Criteria for Stage N (NREM)
  - If all epochs of NREM contain no recognizable sleep spindles, K complexes or high amplitude 0.5-2 Hz slow wave activity, score all epochs of NREM sleep as stage N (NREM)

General Scoring of Sleep Stages in Pediatrics

- Criteria for Stage N2 (NREM 2)
  - If some epochs of NREM contain sleep spindles or K complexes, score those as N2. If in the remaining NREM epochs, there is no slow wave activity comprising more than 20% of the epoch, score as stage N (NREM)
- Criteria for Stage N3 (NREM 3)
  - If some epochs of NREM contain ≥20% slow wave activity, score these as N3. If in the remaining NREM epochs, there are no K complexes or spindles, then score as stage N (NREM)

Initial Age of Waveform Appearance

Waveform	Age of Initial Appearance
Sleep spindles	6 weeks–3 months post-term
K complexes	3–6 months post-term
Slow wave activity	2–5 months post-term
Posterior dominant rhythm	
• Frequency of 3.5–4.5 Hz	3–4 months post-term
• Frequency of 5–6 Hz	5–6 months post-term
• Frequency of 7.5–9.5 Hz	3 years
• Mean frequency of 9 Hz	9 years
• Mean frequency of 10 Hz	15 years
Vertex sharp waves	4–6 months post-term
Hypnagogic hypersynchrony (HH)	3–6 months post-term

Stage W

- Characteristics:
  - Eye blinks
  - Reading eye movements
  - REMs
  - Posterior dominant rhythm
    - Dominant reactive EEG rhythm over occipital regions in relaxed wakefulness with eyes closed which is slower in infants and young children and attenuates with eye opening or attention
    - Frequency is 3.5-4.5 Hz when first seen in infants 3-4 months post-term, 5-6 Hz by 5-6 months, and 7.5-9.5 Hz by age 3 years and amplitude usually >50 uV

Stage W

- Score as Stage W when more than 50% of epoch contains EITHER or BOTH:
  - Age-appropriate posterior dominant rhythm over occipital region
  - Other findings consistent with Stage W:
    - Eye blinks at frequency of 0.5-2 Hz
    - Reading eye movements
    - Rapid eye movements associated with normal or high chin muscle tone

Development of PDR

- Before 3-4 months: Slow irregular potential changes seen over occipital scalp regions
- By 3-4 months: 75% of infants have irregular 50-100 uV, 3.5-4.5 Hz activity over occipitals which is reactive
  - Reactive = Blocks or attenuates with eye opening and appears with passive eye closure
- By 5-6 months: 50-110 uV, 5-6 Hz activity over occipitals
  - By 12 months, this rhythm present in 70% of normal children

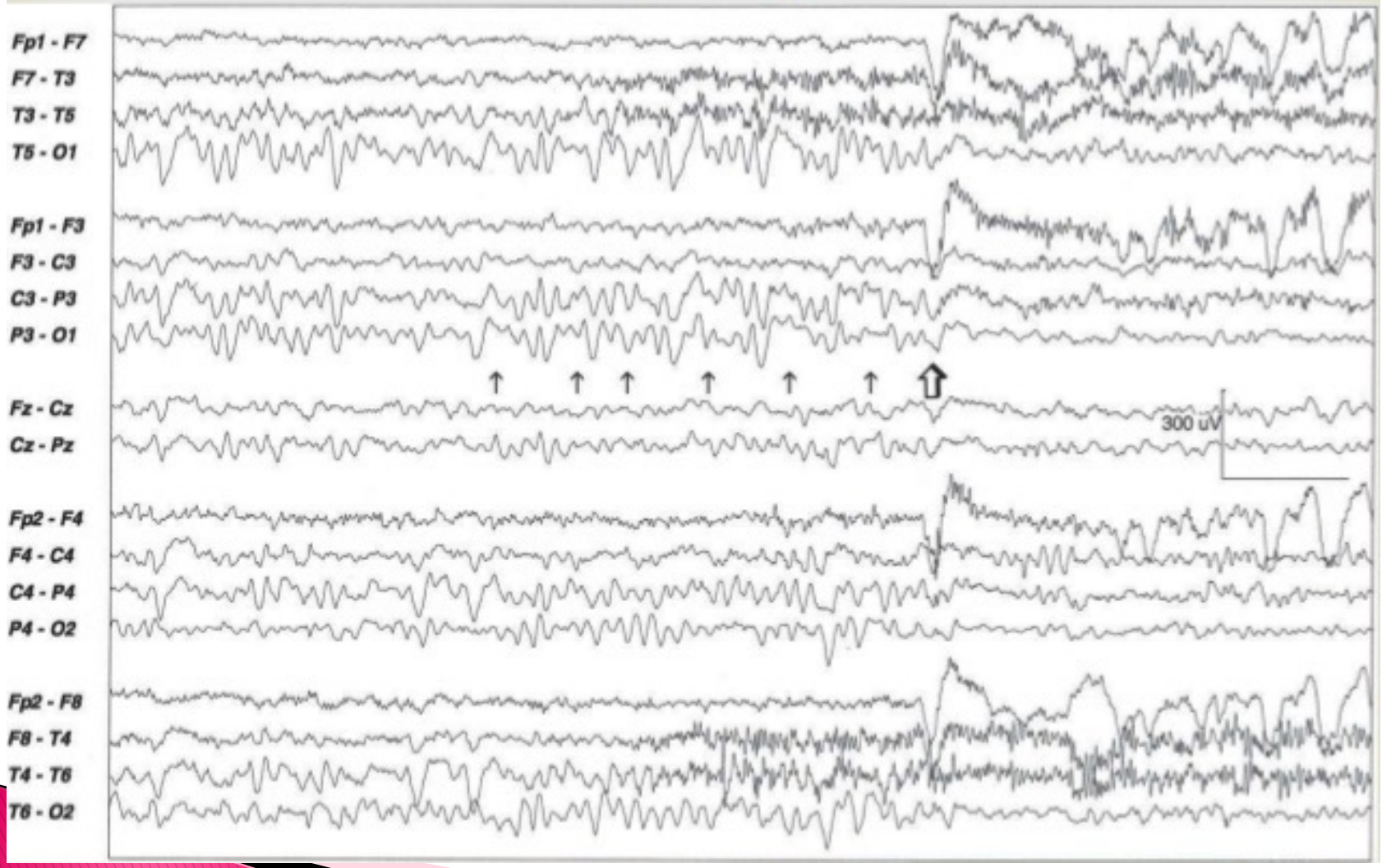
Development of PDR

- By age 3: 82% of children show mean occipital frequency of 7.5-9.5 Hz
- By age 9: 65% of children have mean frequency of 9 Hz
- By age 15: 65% of children have an increased mean frequency of 10 Hz
- Average amplitude of PDR in children is 50-60 uV
  - 9% have > 100 uV
  - Rarely have activity < 30 uV

Slower EEG Rhythms in PDR

- Posterior slow waves of youth (PSW)
  - Intermittent runs of bilateral but often asymmetric 2.5–4.5 Hz slow waves superimposed, riding upon, or fused with PDR, are usually <120% of PDR voltage, block with eye opening and disappear with drowsiness and sleep
  - Uncommon in children <2 years
  - Maximal incidence between age 8–14
  - Uncommon after age 21
- Random or semi-rhythmic occipital slowing (delta—theta)
  - <100 uV, 2.5–4.5 Hz rhythmic or arrhythmic activity lasting <3 seconds
    - Amount of intermixed slowing decreases and frequency increases with increasing age.
  - Normal in EEGs of children 1–15 years
  - Prominent in ages 5–7 years

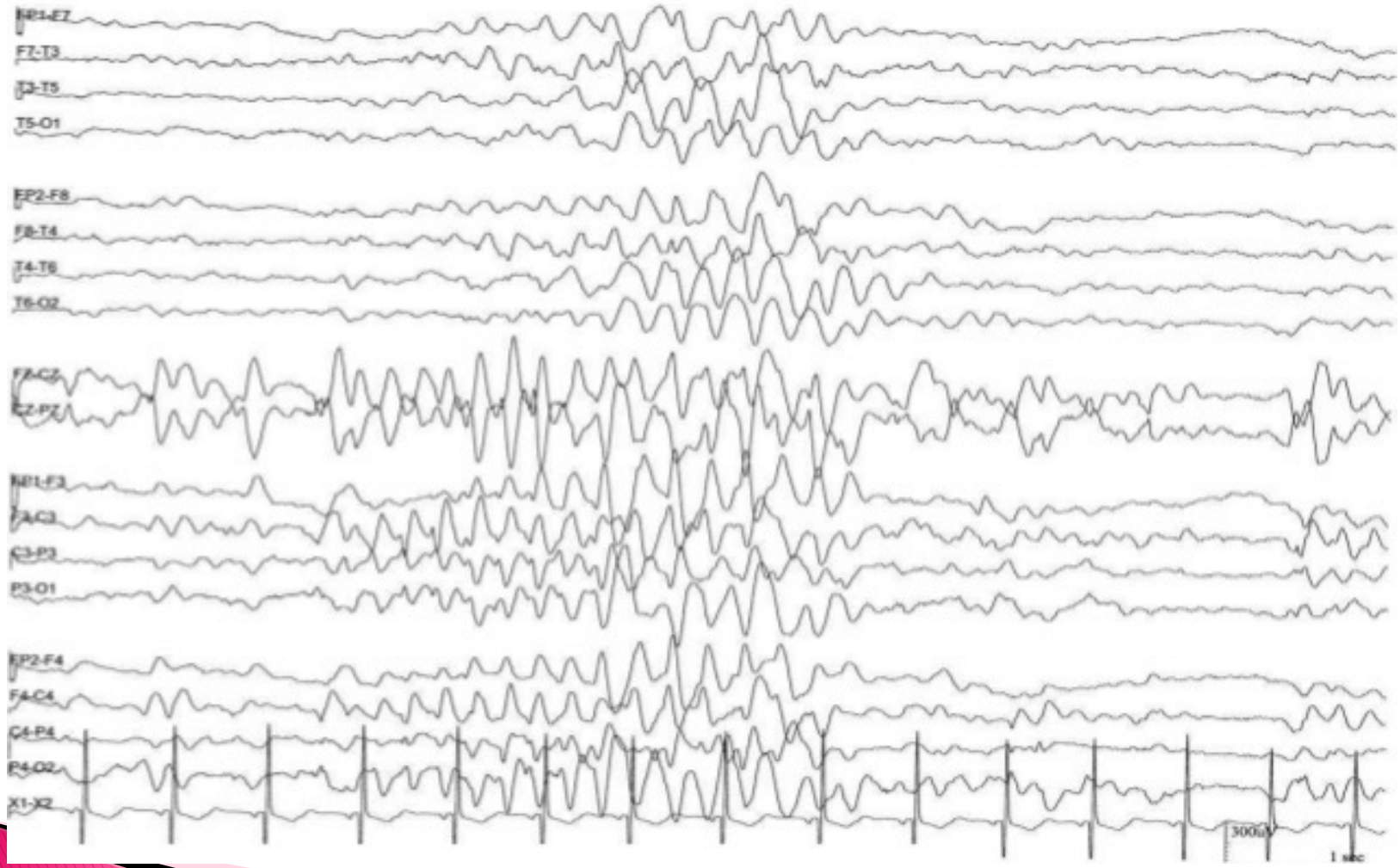
Posterior Slow Waves of Youth Attenuated with Eye Opening



Stage N1

- Score if these characteristics present:
  - Slow eye movements
  - Low-amplitude, mixed frequency activity
  - Vertex sharp waves
  - Hypnagogic hypersynchrony (HH)
    - Paroxysmal bursts or runs of diffuse, high amplitude, sinusoidal, 75-350 uV, 3-4.5 Hz waves which begin abruptly, are usually widely distributed but often maximal over central, frontal, or frontocentral regions
  - PDR is attenuated or replaced by low-amplitude, mixed-frequency activity for more than 50% of epoch

Hypnagogic Hypersynchrony



Stage N1

- If no PDR, score N1 with the earliest of ANY of the following phenomena:
  - Activity in the range of 4–7 Hz with slowing background frequencies by ≥1–2 Hz from those of Stage W
  - Slow eye movements
  - Vertex sharp waves
  - Hypnagogic hypersynchrony
  - Diffuse or occipital-predominant, high-amplitude, rhythmic 3–5 Hz activity

Stage N1 Notes

- In most individuals, sleep onset will be 1st epoch of stage N1, but in infants younger than 2 months, this is often Stage R
- Drowsiness in infants up to 6-8 months of age is characterized by gradual appearance of diffuse, high-amplitude (often 75-200 uV) 3-5 Hz activity which is typically higher amplitude, more diffuse, and 1-2 Hz slower than waking EEG background activity
- Drowsiness in children 8 months to 3 years is characterized by either diffuse runs/bursts of rhythmic/semi-rhythmic bisynchronous 75-200 uV, 3-4 Hz activity often maximal over occipital region and/or higher amplitude (> 200 uV) 4-6 Hz theta activity maximal over frontocentral or central regions

Stage N1 Notes

- Sleep onset from 3 years on is often characterized by 1-2 Hz slowing of PDR frequency and/or PDR often becomes diffusely distributed then is gradually replaced by relatively low-voltage, mixed-frequency EEG activity
- HH is distinctive EEG pattern of drowsiness and Stage N1 that often disappears with deeper stages of NREM sleep
  - Seen in approx. 30% of infants at 3 months post-term, 95% of all normal children ages 6-8 months, and less prevalent after age 4-5 years
  - Seen only in 10% of healthy children by age 11 years and rarely seen after age 12 years

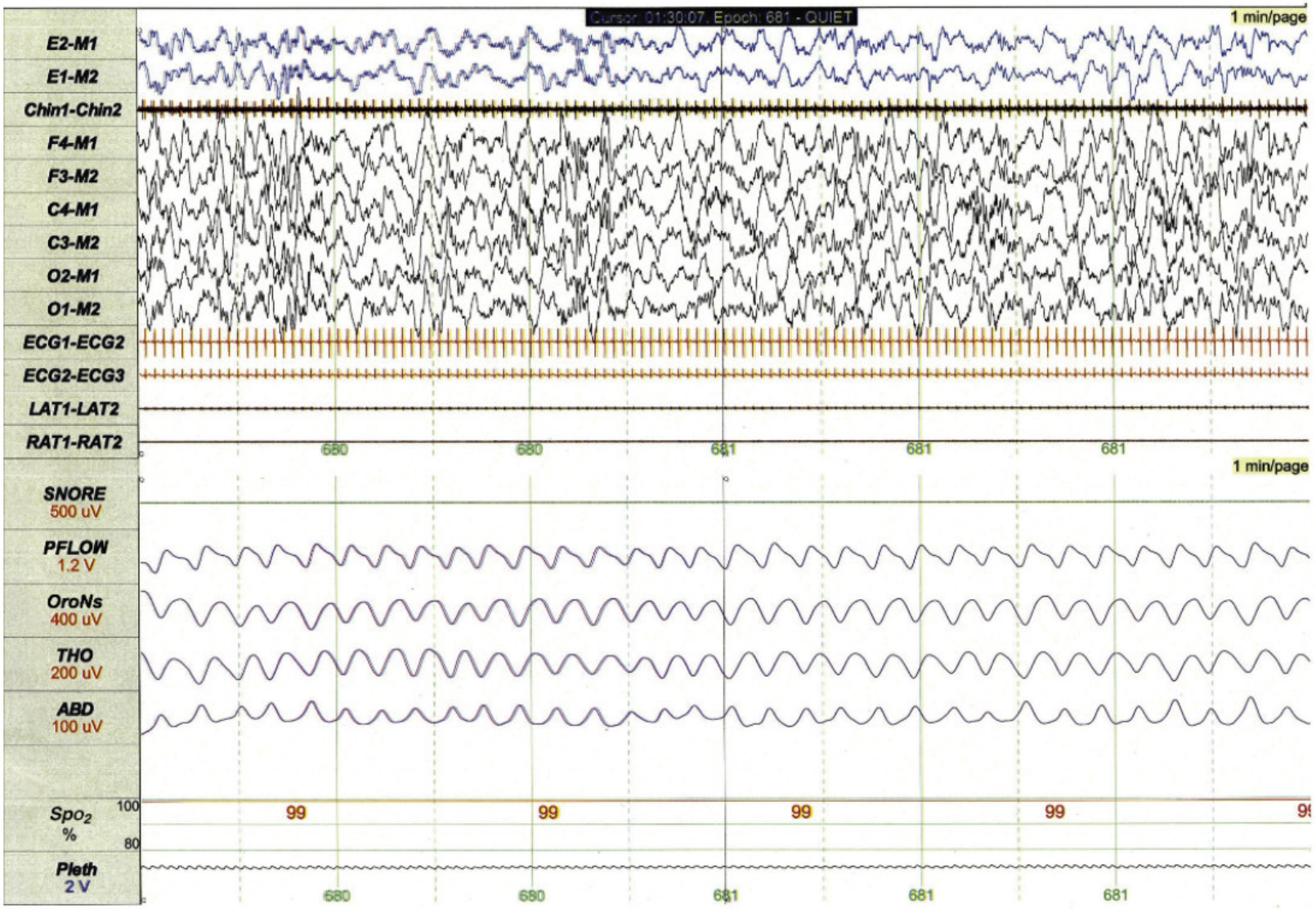
Stage N2

- Criteria for Stage N2
  - Same as the adult rules
  - Spindles may be seen by age 6 weeks–3 months post-term
    - Usually first seen in infants 4–6 weeks post-term
    - Present in all infants by age 3 months post-term
      - Spindles are asynchronous between hemispheres at this age but become more synchronous over first year of life
    - Low-amplitude 12–14 Hz activity maximal in vertex region
    - Usually well-developed and present in all normal infants by 8–9 weeks
    - 80% of children < 13 years have 2 independent scalp locations and frequency ranges for spindles
      - 10–12.75 Hz over frontal and 12.5–14.75 Hz over central/centroparietal region
  - K complexes are present 5–6 months post-term
    - Maximal over pre-frontal and frontal regions

Stage N3

- Criteria for Stage N3
  - Same as adult rules
  - Slow wave activity may first appear by 2 months old and usually present by 3–4.5 months post-term
    - Slow wave activity is often 100–400 μV, 0.5–2.0 Hz activity, maximal over the frontal scalp regions when it first appears in infants
      - But the criteria for slow wave activity is the same as for adults: > 75 μV amplitude and 0.5–2 Hz frequency

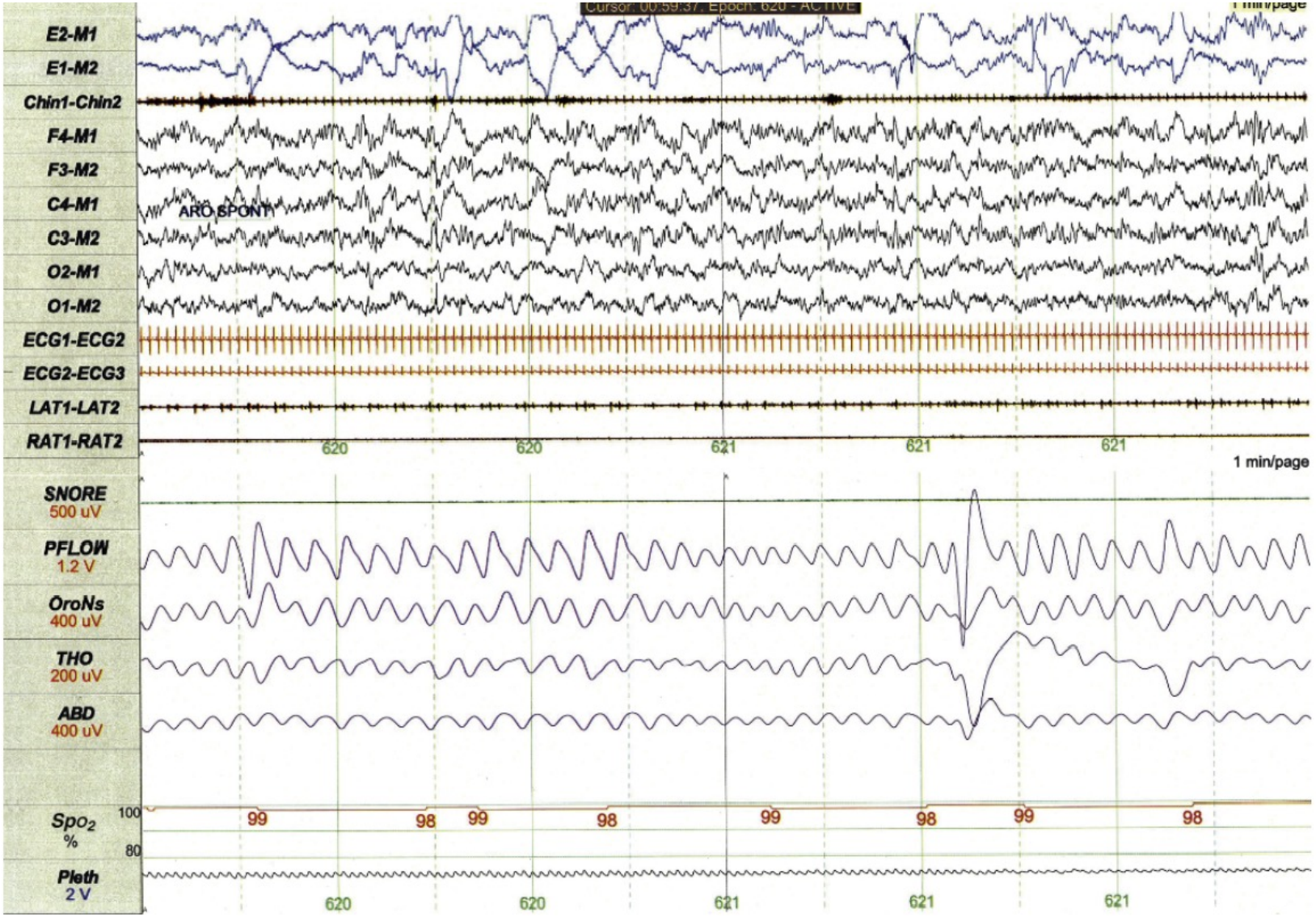
Pediatric N3 Sleep



Stage REM

- Stage R
  - Same as adult rules
  - The continuous, low-amplitude, mixed-frequency EEG activity of stage R in infants and children resembles adults although the dominant frequencies increase with age:
    - 7 weeks old = 3 Hz
    - 5 months = 4-5 Hz with sawtooth waves
    - 9 months = 4-6 Hz
    - 1-5 years = Notched 5-7 Hz theta appear
    - 5-10 years = Like that of adults

Stage REM


E2-M1
E1-M2
Chin1-Chin2
F4-M1
F3-M2
C4-M1
C3-M2
O2-M1
O1-M2
ECG1-ECG2
ECG2-ECG3
LAT1-LAT2
RAT1-RAT2
ARO SPONT
620
620
621
621
621
1 min/page
SNORE
500 uV
PFLOW
1.2 V
OroNs
400 uV
THO
200 uV
ABD
400 uV
SpO2
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99
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2 V
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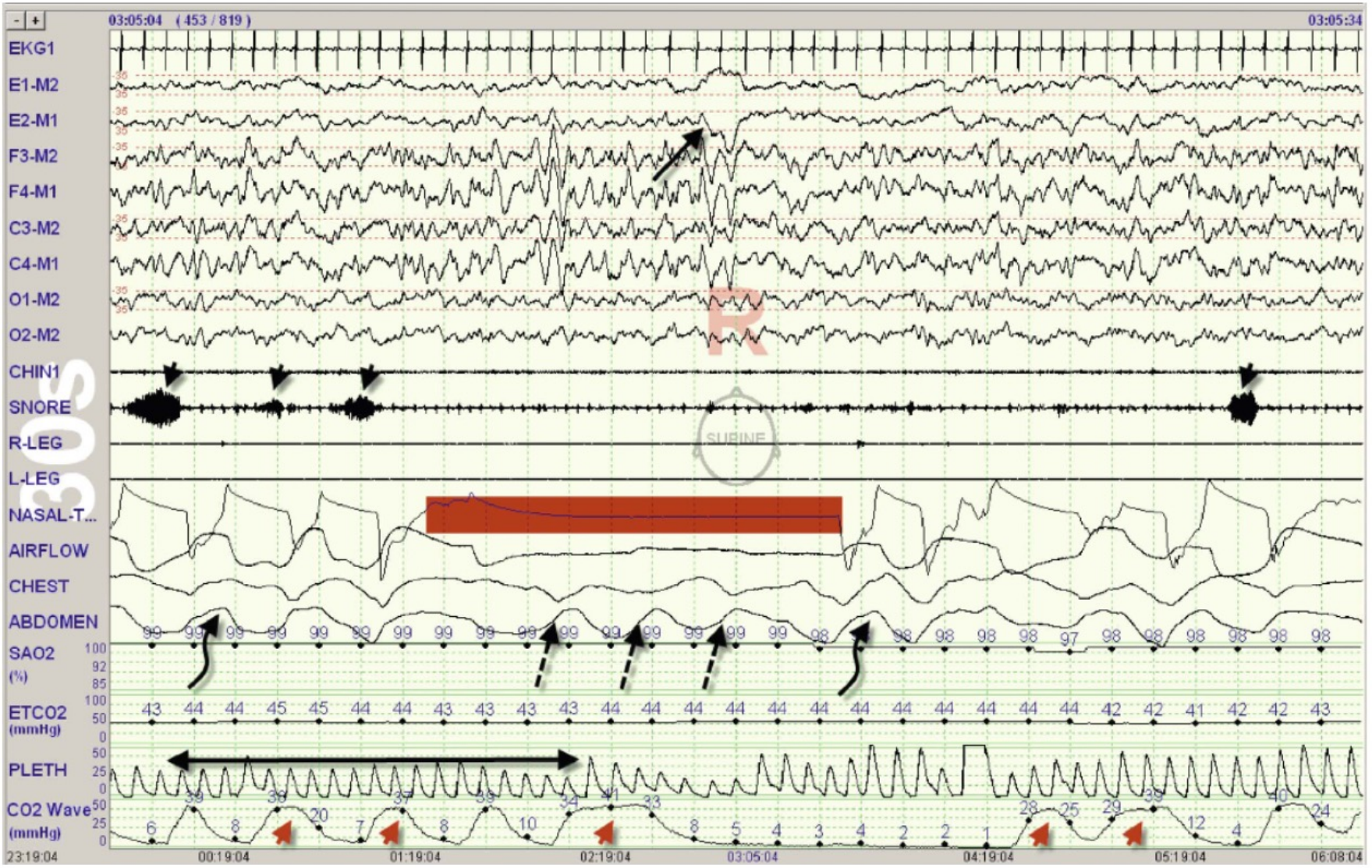
621
621

Respiratory Rules

- Can be used for children < 18 years but can score children using adult criteria ≥ 13 years with adult body habitus

- AHI will be higher in teens if following pediatric rules vs. adult rules

Scoring Apneas



Technical Specifications

- Use oronasal thermal airflow sensor to detect apneas
  - If not functioning or not available, use:
    - Recommended devices:
      - Nasal pressure transducer
      - RIPsum
      - RIPflow
    - Acceptable device:
      - End-tidal PCO2
      - PVDFsum

Technical Specifications

- Use nasal pressure transducer to detect hypopneas
  - If not functioning or not available, use:
    - Recommended devices:
      - Oronasal thermal airflow
      - RIPsum
      - RIPflow
      - Dual thoracoabdominal RIP belts
    - Acceptable device:
      - PVDFsum
- During PAP titration, use PAP device flow signal to detect apneas and hypopneas

Technical Specifications

- For respiratory effort, use one of these:
  - Esophageal manometry
  - Dual thoracoabdominal RIP belts
  - Acceptable but not recommended is dual thoracoabdominal PVDF belts
- O2 saturation detection, snoring monitoring, and hypoventilation detection are the same as adults

Scoring Apneas

- Length duration is different for pediatrics
  - For obstructive apneas:
    - Instead of 10 seconds, it is 2 missed breaths with respiratory effort present
  - For mixed apneas:
    - 2 missed breaths and absent respiratory effort during one portion and inspiratory effort in another portion
  - For central apneas:
    - No inspiratory effort and at least one of following:
      - Lasts $\geq$ 20 seconds
      - At least 2 missed breaths and associated with arousal or a $\geq$ 3% arterial oxygen desaturation
      - At least 2 missed breaths and associated with decrease in HR to $<$ 50 bpm for at least 5 seconds or for infants under 1 year only $<$60 bpm for 15 seconds

Scoring Respiratory Events

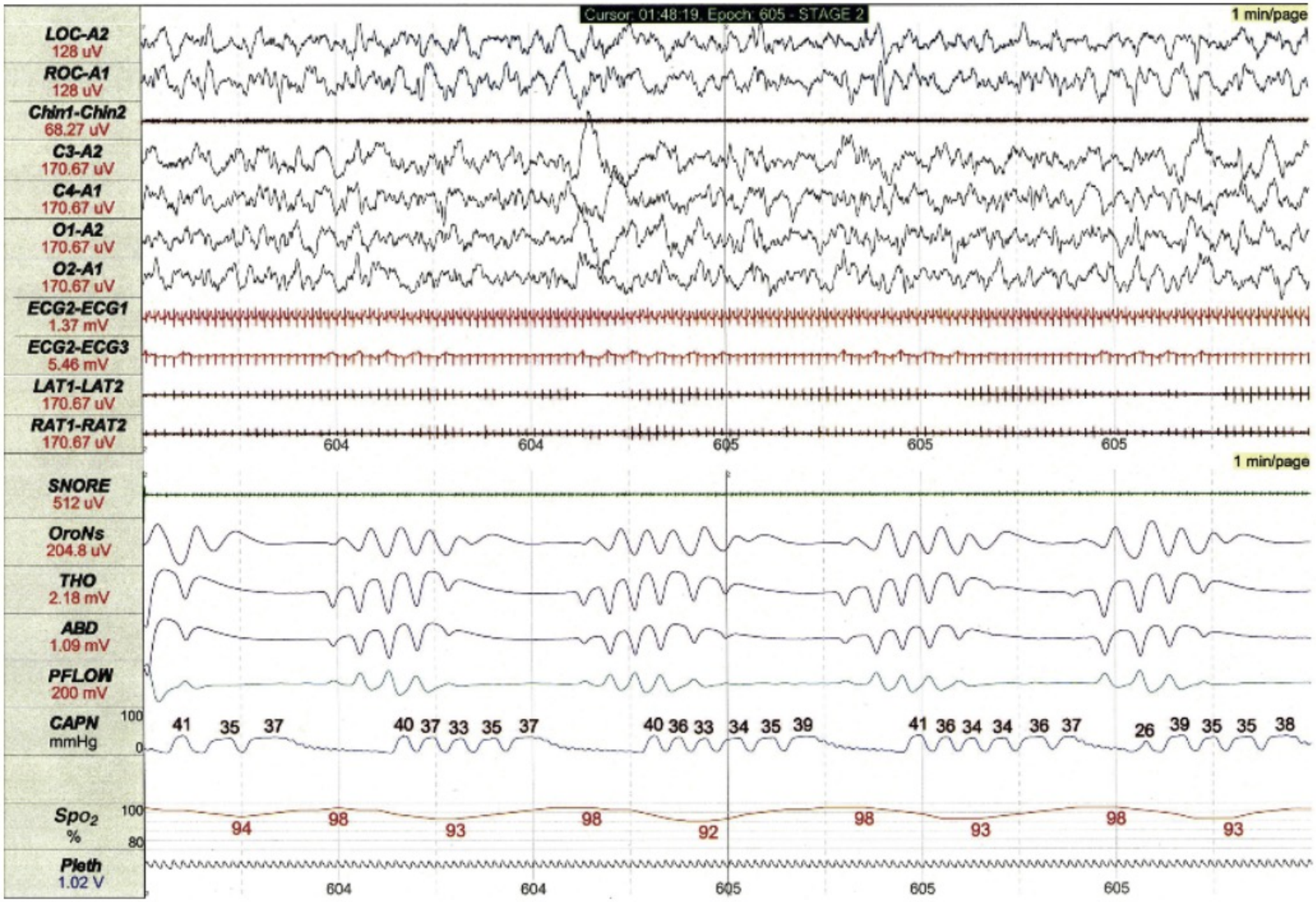
- For hypopneas:
  - Flow signals drop by ≥ 30%
  - Duration last for ≥ 2 breaths
  - ≥3% oxygen desaturation from pre-event baseline or the event is associated with an arousal
  - Rules for obstructive and central hypopneas are same as adults
- RERA criteria same as adults except duration is minimum of 2 missed breaths

Scoring Respiratory Events

- Hypoventilation
  - Recommended to monitor in children during diagnostic study
  - Optional during a PAP titration
  - Use etCO2 or TcCO2 for detection
  - $>$ 25% of TST has PCO2 $>$ 50 mm Hg

- Periodic breathing
  - $\geq$ 3 episodes of central apnea last $>$ 3 seconds separated by $\leq$ 20 seconds of normal breathing

Periodic Breathing



Special Circumstances for Scoring Respiratory Events

- Score a respiratory event occurring during PAP device-triggered breaths as a central apnea if all the following are met:
  - Decrease in PAP flow signal meeting apnea criteria
  - Device triggered pressure pauses (pressure support) occur during the event
  - No evidence of spontaneous (patient-triggered) respiratory effort during the event