

University of Texas Medical Branch, Sleep Disorder Center Policy: 08.06.19 Scoring Sleep Stage: Pediatric	Effective Date: Revised Date: January 2013 Review Date:
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## SCORING SLEEP STAGE: PEDIATRICS

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- Audience:** All personnel in the Sleep Disorder Center.
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- Purpose:** To establish and formalize the scoring system of sleep stage in the pediatric patient 2 months post-term or older. All sleep records will be scored using established criteria by latest edition of *The American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events, Rules Terminology and Technical Specifications*.
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- Policy:** The following measures are indicated for scoring sleep stage of pediatric sleep studies.
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- Procedure:**
- General Considerations:*
- All sleep recordings on pediatric patients will be scored for sleep stage using the criteria established by the latest edition of *The American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events, Rules, Terminology and Technical Specifications*.
  - Standard definitions will be used for all sleep-related terminology.
  - Sleep-related definitions will conform to the Clinical Practice Parameters set by the American Academy of Sleep Medicine (AASM) where they exist.
- Monitoring Sleep For Staging:*
- Electroencephalogram (EEG) electrode placement is by the accurate measurement of the skull according to the International 10-20 System of Electrode Placement which is required for recording EEG activity during sleep and for documenting and localizing epileptiform activity.
  - Recommended derivations are: F4-M1, C4-M1, O2-M1. Backup electrodes should be placed at F3-M2, C3-M2, O1-M2.
  - M2 and M1 are the right and left mastoids, respectively.
  - Electrooculogram (EOG) measure eye movements. Recommended derivations are E1/M2, where E1 is placed 1 cm below the left outer canthus (LOC) and E2/M2, where E2 is placed 1 cm above the right outer canthus (ROC). Alternative acceptable derivations are: Place E1 1 cm below and 1 cm lateral to the LOC and E2 1 cm below and 1 cm lateral to the ROC.
  - Electromyogram (EMG) monitor chin muscle activity. Three electrodes are recommended. One in midline 1 cm above the inferior edge of the mandible. One 2 cm below the inferior edge of the mandible and 2 cm to the right of midline. One 2 cm below the inferior edge of the mandible and 2 cm to the left of the midline.

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- EMG derivations consist of either of the electrodes below the mandible referred to the electrode above the mandible. The other inferior electrode is a backup should one of the primary electrodes malfunction.

*Technical Considerations:*

- See Adult EEG, EOG and EMG sleep scoring rules and digital PSG section for technical considerations other than those in the notes below:
  1. Adult electrode derivations for EEG, EOG and chin EMG are acceptable for recording sleep except that the distance from the chin EMG electrodes often needs to be reduced from 2 cm to 1 cm and the distance from the eyes in EOG electrodes often need to be reduced from 1 cm to 0.5 cm in infants and children with small heads.
  2. An initial EEG sensitivity of  $7\mu\text{V}/\text{mm}$  (vertical scaling) is appropriate for routine PSG recordings but the sensitivity often needs to be adjusted in infants and younger children typically to 10 or even  $15\mu\text{V}/\text{mm}$ . If sensitivities of 10 or  $15\mu\text{V}/\text{mm}$  are used, portions of the sleep recording should be reviewed using  $7\mu\text{V}/\text{mm}$  in order to display and recognize low voltage faster frequencies (including spindle frequencies).
  3. An initial EEG sensitivity of  $150\mu\text{Vp-p}$  is appropriate for routine PSG recordings but the sensitivity often needs to be adjusted in infants and younger children typically to  $200\mu\text{Vp-p}$ . If sensitivities are increased, portions of the sleep recording should be reviewed using  $150\mu\text{Vp-p}$  in order to display and recognize low voltage faster frequencies (including spindle frequencies).

*Scoring Sleep Stages:*

- Score sleep stages in 30 second sequential epochs.
- Assign a stage to each epoch.
- If two or more stages coexist during a single epoch, assign the stage comprising the greatest portion of the epoch.
- Keyboard Designations: Use the number key pad on the keyboard to designate sleep stage.
  - 0 - Wake
  - 1 - Stage 1
  - 2 - Stage 2
  - 3 - Stage 3

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5 - REM

Decimal (.) – No Stage

7 – Stage N

- Because of the variability of sleep in infants, four possible scenarios are described below:
  1. If all epochs of NREM sleep contain no recognizable sleep spindles, K complexes or high-amplitude 0.5 to 2 Hz slow wave activity, score all epochs of NREM sleep as stage N (NREM), number 7 on the keyboard (GRASS TWin).
  2. If some epochs of NREM sleep contain sleep spindles or K complexes, score those as stage N2 (NREM 2). If in the remaining NREM epochs, there is no slow wave activity comprising more than 20% of the duration of epochs, score as stage N (NREM).
  3. If some epochs of NREM sleep contain greater than 20% slow wave activity, score these as N3 (NREM 3). If in the remaining NREM epochs, there are no K complexes or spindles then score as stage N (NREM).
  4. If NREM is sufficiently developed that some epochs contain sleep spindles or K complexes and other epochs contain sufficient amounts of slow wave activity, then score NREM sleep in the infant as either stage N1, N2, N3 as in an older child or adult.
  5. Epochs defined by indiscernible EEG data, such as poor signal quality, no head box connection, ie. Patient up for restroom, score a decimal (.), No Stage, for those epochs.

*Notes:*

- Sleep spindles usually are present in NREM sleep of infants 2 to 3 months post-term or older.
- K complexes are usually present in NREM sleep in infants 4 to 6 months post-term or older.
- Slow wave activity ( $\geq 75\mu\text{V}$ , 0.5 – 2 Hz typically in the frontal regions) is usually present 4 to 5 months post-term.
- NREM sleep can be scored as stage N1, N2, or N3 in most infants 5 to 6 months post-term or older, occasionally in infants as young as 4 to 4.5 months post-term.
- Non-EEG correlates are very helpful in recognizing NREM and REM sleep in infants 6 months post-term or younger. These correlates in REM sleep include the presence of irregular respiration, atonic chin EMG, transient muscle activity, and rapid eye movements. In NREM sleep, correlates include regular respiration, no or rare vertical eye movements, and preserved chin EMG tone.

### *Stage Wake*

- Alpha rhythm: Trains of sinusoidal, 8 – 13 Hz activity recorded over the occipital region present with eye closure and which is reactive (attenuates with eye opening).
- Eye blinks: Conjugate vertical eye movements at a frequency of 0.5 – 2 Hz present in wakefulness with 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 child reads or visually scans the environment.
- 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 visually scan the environment.
- Posterior dominant rhythm (PDR): The dominant reactive EEG rhythm over the 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 to 9.5 Hz by 3 years of age and amplitude is usually >50 $\mu$ V.

### *Rules*

- In children the dominant posterior rhythm replaces the term alpha rhythm for the purposes of scoring wakefulness and NREM stages.
- Score epochs as stage W when more than 50% of the epoch has either reactive alpha or age-appropriate dominant posterior rhythm (DPR) over the occipital region.
- If there is no discernible reactive alpha or no age-appropriate dominant posterior rhythm, score epochs as stage W if any of the following are present:
  1. Eye blinks at a frequency of 0.5 – 2 Hz
  2. Reading eye movements
  3. Irregular conjugate rapid eye movements associated with normal or high chin muscle tone

### *Notes:*

- The dominant posterior rhythm (DPR) over the occipital derivations in adults has amplitude of <50  $\mu$ V, a frequency of 8.5 to 13 Hz, and is reactive to eye opening. The frequency and amplitude of the DPR over the occipital in children changes with age.

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- a) Only slow irregular potential changes are seen over the occipital scalp regions in infants before 3 to 4 months post-term.
- b) Seventy-Five percent of infants by 3 to 4 months post-term have an irregular 50–100  $\mu\text{V}$ , 3.5 to 4.5 Hz activity over the occipital regions which is reactive (I.e., blocks or attenuates with eye opening and appears with passive eye closure).
- c) By 5 to 6 months of age, many children have 50 to 110  $\mu\text{V}$ , 5–6 Hz activity over the occipital regions, and this rhythm is present in 70% of normal children by age 12 months.
- d) By 3 years of age, 82% of children who were normal post-term infants show a mean occipital frequency of  $>8$  Hz.
- e) A mean alpha frequency of 9 Hz is found in 65% of 9 year olds and increases to 10 Hz in 65% by age 15.
- f) The average amplitude of the DPR in children is 50-60 $\mu\text{V}$ ; 9% of children have. 100  $\mu\text{V}$  (especially between 6-9 years); children rarely have alpha activity  $<30$   $\mu\text{V}$ .

*Notes continued:*

- The highest amplitude and sharpest component of reading eye movements in children is 50-60  $\mu\text{V}$  is usually surface-negative in the occipital derivations, typically last 150 to 250 msec, and have amplitudes up to 65  $\mu\text{V}$ .
- Occipital sharp waves with eye blinks are typically single monophasic or biphasic  $<200$   $\mu\text{V}$  sharp waves over the occipital derivations which usually last 200 to 400 msec and occur 100 to 500 msec following an eye blink or eye movement. In children, the initial component of the occipital sharp wave is surface-positive; the ascending phase of next surface-negative component has a steep wave front; and the descending phase of the second component less steep.
- The dominant posterior rhythm (DPR) in infants and children typically contains intermixed slower EEG rhythms including:
  - Posterior slow waves of youth (PSW) which are intermittent runs of bilateral but often asymmetric 2.5-4.5 Hz slow waves superimposed, riding upon, or fused with the DPR, are usually  $<120\%$  of DPR voltage, block with eye opening and disappear with drowsiness and sleep. PSW are uncommon in children  $<2$  years of age, have a maximal incidence between ages 8 to 14 years, and are uncommon after age 21 years.

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- Random or semi-rhythmic occipital slowing: <math><100\mu V</math>, 2.5 to 4.5 Hz rhythmic or arrhythmic activity lasting <math><3</math> seconds; a normal finding in EEGs of children ages 1 to 15 years, especially prominent ages 5 to 7 years; the amount of intermixed slowing decreases and its frequency increases with increasing age.
- Spontaneous eye closure in infant signals drowsiness.

***Stage N1***

- Slow eye movements (SEM):
- In subjects who generate a dominant posterior rhythm, score stage N1 if the posterior rhythm is attenuated or replaced by low amplitude mixed frequency activity for more than 50% of the epoch.
- In subjects who do not generate a DPR, score stage N1 commencing with the earliest of any of the following phenomena:
  - Activity in the range of 4-7 Hz with slowing of background frequencies by  $\geq 1-2$  Hz from those of stage W.
  - Slow eye movements
  - Vertex sharp waves
  - Rhythmic anterior theta activity (RAT)
  - Hypnagogic hypersynchrony
  - Diffuse or occipital predominant high amplitude rhythmic 3-5 Hz activity.

***Notes:***

- Drowsiness in infants up to age 6 to 8 months is characterized by the gradual appearance of diffuse high amplitude (75 to 200 $\mu V$ ), 3-5 Hz activity which is typically of higher amplitude, more diffuse, and 1-2 Hz slower than the waking EEG background activity.
- Drowsiness in children 8 months to 3 years is characterized by either diffuse runs or bursts of rhythmic or semi-rhythmic bisynchronous 75 to 200 $\mu V$ , 3-4 Hz activity often maximal over the occipital regions and /or higher amplitude (>299 $\mu V$ ), 4-6 Hz theta activity maximal over the frontocentral or central regions.
- Sleep onset from 3 years on is often characterized by a 1-2 Hz slowing of the dominant posterior rhythm frequency and/or the dominant posterior rhythm often becomes diffusely distributed then is gradually replaced by relatively low voltage mixed frequency EEG activity.

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- In most subjects sleep onset will be the first epoch of stage N1 but in infants younger than 3 months post-term, this is often stage R.
- Rhythmic anterior theta activity (RAT) are runs of moderate voltage 5-7 Hz theta activity over the frontal regions is commonly seen in adolescents and young adults when drowsy, may first appear around 5 years of age.
- Vertex sharp waves are monophasic surface-negative sharp waves maximal over the central regions which last <0.5 second, can occur in bursts or runs, most often seen during transition to stage N1 sleep but can occur in either stage N1 or N2 sleep. By 6 months post-term, a few broad vertex sharp waves can be seen over the central regions but vertex sharp waves which resemble those seen in older children and adults typically first appear 16 months post-term.
- Hypnagogic hypersynchrony (HH) is a distinctive EEG pattern of drowsiness and stage N1 characterized by paroxysmal runs or bursts of diffuse bisynchronous 75 to 350  $\mu$ V, 3-4.5 Hz waves often maximal over the central, frontal or frontocentral or derivations. HH often disappears with deeper stages of NREM sleep. HH is seen in approximately 30% of infants 3 months post-term, 95% of all normal children ages 6 to 8 months, and is less prevalent after age 4 or 5 years, seen in only 10% of healthy children age 11, rarely seen after age 12 years.

### *Stage N2*

- Defined by the presence of sleep spindles (12 – 14 cps activity lasting at least 0.5 seconds) and K-complexes (well –delineated negative sharp wave immediately followed by a positive component with a duration  $\geq$ 0.5 seconds).
- Begin scoring stage N2 if one or more K-complexes not associated with arousals, and/or one or more trains of sleep spindles occur during the first half of that epoch or occur during the last half of the previous epoch.
- Continue to score epochs with low amplitude, mixed frequency EEG activity without K-complexes or sleep spindles stage N2 if they are preceded by 1) K-complexes unassociated with arousals or 2) sleep spindles.
- End stage N2 when one of the following occurs: 1) transition to W, 2) transition to stage N1 due to arousal or major body movement, 3) transition to stage N3, 4) transition to stage R.

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*Notes:*

- Sleep spindles (SS) are usually first seen in infants 4 to 6 weeks post-term as brief bursts of low amplitude less sinusoidal 12-14 Hz activity maximal over the vertex (C<sub>z</sub>) region, are usually well-developed and are present in all normal infants 8 to 9 weeks.
- Eighty percent of children <13 years of age have two independent scalp locations and frequency ranges for sleep spindles: 10.0 to 12.75 Hz over the frontal and 12.5 to 14.75 maximal over the central or centroparietal region.
- Frontal sleep spindles are more prominent than centroparietal spindles in young children but abruptly decrease in EEG power and presence beginning at age 13 whereas centroparietal spindles persist unchanged in presence or location.
- K complexes are usually present 5 to 6 months post-term and are maximal over the pre-frontal and frontal regions, as they are in adults.

***Stage N3***

- Defined as slow wave activity (a frequency of 0.5Hz to 2 Hz and a peak to peak amplitude >75 μV) persisting for 20% or more of the epoch.
- Sleep spindles may be present, eye movements are typically not seen and chin EMG is of variable low amplitude. □

*Notes:*

- Slow wave activity in pediatric populations often 100 to 400 μV, 0.5 to 2.0 Hz activity maximal over the recommended derivations in the frontal scalp regions (F<sub>4</sub>, F<sub>z</sub>) first appears as early as 2 months, more often about 3 to 4.5 months post-term.

***Stage REM***

- Defined by the appearance of relatively low voltage, mixed frequency EEG activity accompanied by episodic REMs. The EEG pattern resembles the one described in Stage 1, except that vertex sharp waves are not prominent in Stage REM. “Saw-tooth” waves may be noted with bursts of REM. Alpha activity may be somewhat more prominent during Stage REM than during Stage 1 and the frequency is generally 1-2 cps slower than during wakefulness. There is an absence of K-complexes and sleep spindles.
- Score epochs at the transition between stage N2 and R as follows:  
1) In between epochs of stage NR (non-REM) and R, score an epoch R if the previous epoch was R and if during the first half of

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the next epoch the chin EMG drops even in the absence of REMs and there is, a) an absence of non-arousal associated K-complexes and b) an absence of sleep spindles. 2) In between epochs of stage N2 and R, score an epoch N2 if the previous epoch was R and if during the first half of the next epoch the chin EMG is down and there is a) an absence of REMs and b) a presence of non-arousal associated K-complexes or sleep spindles. 3) In between epochs of stage N2 and R, score an epoch R if the previous epoch was R and if during the first half the next epoch the chin EMG has minimal tone and there are a) the absence of REMs, b) the absence of non-arousal associated K-complexes and c) the absence of sleep spindles.

- Continue to score stage R even without the presence of REMs if the EEG shows low amplitude, mixed frequency activity without K-complexes or sleep spindles and the chin EMG tone remains low.
- End stage R when the following occurs: 1) there is a transition to W, N3, N2) there is an increase in chin EMG tone and N1 criteria are met, 3) one or more non-arousal associated K-complexes or sleep spindles are present in the first half of the epoch and there are no REMs even if the chin EMG remains low.
- For further details on staging see *The American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events, Rules, Terminology and Technical Specifications* pages 27 – 31.

*Notes:*

- The continuous low voltage, mixed frequency EEG activity of stage R in infants and children resembles adults though the dominant frequencies increase with age: approximately 3 Hz activity at 7 weeks post-term; 4-5 Hz activity with bursts of saw tooth waves at 5 months; 4-6 Hz at 9 months; and prolonged runs or bursts of notched 5-7 Hz theta activity at 1 to 5 years age. By 5 to 10 years of age, the low voltage mixed frequency activity in stage R resembles that of adults.

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Shahzad Jokhio, M.D.  
Medical Director