The Development of Sleep in Infants and Children
Focus 2017

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Objectives

- At the completion of this session the attendees will be able to
  - Describe the progression of normal sleep from infancy through the school aged child
  - Summarize the most common age related sleep disturbances/disorders
  - Assess the bi-directionality between behavioral and physiologically sleep related issues
Objectives for Premie/Neonatal and Infant Sleep

• Describe the progression of sleep over the first year of life
• Consider the importance of maturational milestones captured on the EEG
• Define corrected age
Sleep

- Important neurological marker of maturation
- What is not there is important too!
- Parental, cultural and ecological factors interact bi-directionally
  - Breast vs bottle feeding
  - Negative sleep associations
  - Bed sharing

Redecker, Developmental Aspects of Normal Sleep in Redecker and McEnany 2011)
Terms to Know-Premie/Neonate

• Trace Discontinue
• Trace Alternant

Age Terminology During the Perinatal Period

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Units of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age</td>
<td>Time elapsed between the first day of the last menstrual period and the day of delivery</td>
<td>Completed weeks</td>
</tr>
<tr>
<td>Chronological age</td>
<td>Time elapsed since birth</td>
<td>Days, weeks, months, years</td>
</tr>
<tr>
<td>Postmenstrual age</td>
<td>Gestational age + chronological age</td>
<td>Weeks</td>
</tr>
<tr>
<td>Corrected age</td>
<td>Chronological age reduced by the number of weeks born before 40 weeks of gestation</td>
<td>Weeks, months</td>
</tr>
</tbody>
</table>

AAP, 2004
Age terminology during the perinatal period.
Circadian Rhythm Development

- The circadian timing system undergoes major developmental changes within the first months after birth:
  - At age 1 month, the 24-h core body temperature rhythm emerges;
  - At age 2 months, infants begin to sleep more at night than during the day;
  - At age 3 months, endogenous production of the circadian driven hormones melatonin, cortisol starts to cycle in a 24-h rhythm.
Sleep Consolidation
A 5-step process should be performed when analyzing a neonatal EEG. The 5 steps consist of the following:

- Knowledge of the post-conceptional age and topography of the infant's head
- Identification of artifacts in the EEG
- Identification of sleep and wake states
- Feature extraction
- Classification of the record as normal or abnormal and the clinical correlation provided to the clinician

Important to Know

- EEG matures according to time
- Maturational milestones
  - Sleep spindles
  - K-Complex
  - Discontinuous → Continuous
- Sleep features
  - REM onset until ~4 months
  - Sleep cycles ~50-60 min
  - REM sleep ~50% TST, gradually decreasing

- Synchrony: this term refers to the simultaneous appearance of morphologically identical waveforms in areas on the same side or opposite sides of the head.
- Symmetry: symmetry refers to the occurrence of approximately equal amplitude, frequency, and form of EEG activities over homologous areas on opposite sides of the head.

- 10/20 System VERY important
AASM Scoring Rules

A. Ages for Which Infant Sleep Staging Rules Apply

1. Infant sleep staging rules should be used to score sleep and wakefulness in infants 0-2 months post-term (37-48 weeks conceptional age). N1, N2, N3, N4. RECOMMENDED

Note 1. Conceptional age (CA) is gestational age (GA) at birth plus the number of weeks postpartum. GA is the time elapsed between the first day of the mother’s last menstrual period and the day of delivery expressed in completed weeks. If the pregnancy was achieved using assisted reproductive technology, GA is calculated by adding 2 weeks to the CA. Chronological age (or postnatal or legal age) is the time elapsed since birth (can be expressed in days, months, or years).

Note 2. At birth, an infant is classified as one of the following: premature (<37 weeks gestation); full-term (37-42 weeks); or post-term (born after 42 weeks). A neonate is a child during the first 28 days after birth; an infant is a child age 1 to 12 months.¹

Note 3. Knowing an infant’s CA is crucial for interpreting the normalcy, immaturity or abnormality of an EEG or PSG because the brain and the EEG continue to develop and mature at a similar rate independent of whether the infant is in utero or post-delivery.

Note 4. For premature infants (<37 weeks CA) refer to discussion in the Pediatric and Infant Scoring Task Force review paper. ²
AASM Scoring Rules

A. Ages for Which Pediatric Sleep Staging Rules Apply

1. Pediatric sleep staging rules can be used to score sleep and wakefulness in children 2 months post-term or older.\textsuperscript{N1,N2}

Note 1. For children less than 2 months post-term, refer to IV. Sleep Staging Rules Part 3: Rules for Infants.

Note 2. There is no precise upper age boundary for pediatric sleep staging rules; refer to discussion in the Pediatric Task Force review paper.\textsuperscript{1}
C. General Scoring of Sleep Stages

1. The following terminology should be used when scoring sleep in children 2 months post-term or older:
   a. Stage W (Wakefulness)
   b. Stage N1 (NREM 1)
   c. Stage N2 (NREM 2)
   d. Stage N3 (NREM 3)
   e. Stage N (NREM)
   f. Stage R (REM)

Because of the variability of sleep in infants, 4 possible scenarios for scoring NREM sleep are described below:

2. If all epochs of NREM sleep 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).

3. 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).

4. If some epochs of NREM sleep contain greater than 20% slow wave activity, score these as stage N3 (NREM 3). If in the remaining NREM epochs, there are no K complexes or spindles then score as stage N (NREM).

5. 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 this infant as either stage N1, N2 or N3 as in an older child or adult.
# Maturational Features

## Table 1. Initial Age of Waveform Appearance.

<table>
<thead>
<tr>
<th>Waveform</th>
<th>Age of Initial Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep spindles</td>
<td>6 weeks - 3 months post-term</td>
</tr>
<tr>
<td>K complexes</td>
<td>3-6 months post-term</td>
</tr>
<tr>
<td>Slow wave activity</td>
<td>2-5 months post-term</td>
</tr>
<tr>
<td>Posterior dominant rhythm</td>
<td></td>
</tr>
<tr>
<td>Frequency of 3.5-4.5 Hz</td>
<td>3-4 months post-term</td>
</tr>
<tr>
<td>Frequency of 5-6 Hz</td>
<td>5-6 months post-term</td>
</tr>
<tr>
<td>Frequency of 7.5-9.5 Hz</td>
<td>3 years</td>
</tr>
<tr>
<td>Mean frequency of 9 Hz</td>
<td>9 years</td>
</tr>
<tr>
<td>Mean frequency of 10 Hz</td>
<td>15 years</td>
</tr>
<tr>
<td>Vertex sharp waves</td>
<td>4-6 months post-term</td>
</tr>
<tr>
<td>Hypnagogic hypersynchrony (HH)</td>
<td>3-6 months post-term</td>
</tr>
</tbody>
</table>
C. General Scoring of Sleep Stages

1. The following terminology should be used when scoring sleep in infants 0-2 months post-term (37-48 weeks CA):^N1,N2
   a. Stage W (Wakefulness)
   b. Stage N (NREM)
   c. Stage R (REM)
   d. Stage T (Transitional)

2. Score epochs using the following rules: ^RECOMMENDED
   a. Score sleep stages in 30-second, sequential epochs commencing at the start of the study
   b. Assign a stage to each epoch
   c. If two or more stages coexist, assign the stage comprising the greatest portion of the epoch
   d. If two or more PSG characteristics are discordant for stage R or stage N sleep, score the epoch as stage T (Transitional) sleep
   e. Score sleep onset as the first epoch of sleep^N3

3. Sleep and wakefulness in infants 38 to 48 weeks CA are scored based on behavioral observation; regularity or irregularity of respiration; and EEG, EOG, and chin EMG patterns defined in Tables 1-6. ^RECOMMENDED

4. Score sleep based on behavioral characteristics as defined in Table 1. ^N4  ^RECOMMENDED
### AASM Scoring Rules-Infants

#### Table 1. Behavioral characteristics of sleep stages.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Behavioral Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake</td>
<td>Calm or active with eyes open, scanning eye movements; brief eye closure can occur with crying</td>
</tr>
<tr>
<td>N</td>
<td>Eyes closed, few movements, sucking can occur</td>
</tr>
<tr>
<td>R</td>
<td>Eyes closed, REM seen under closed eyelids, squirming, sucking, grimacing, small movements of the face or limbs</td>
</tr>
</tbody>
</table>

#### Table 2. Respiration characteristics of sleep stages.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Respiration Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake</td>
<td>Irregular, rapid, and shallow</td>
</tr>
<tr>
<td>N</td>
<td>Regular</td>
</tr>
<tr>
<td>R</td>
<td>Irregular, some central pauses (may or may not meet criteria for apnea)</td>
</tr>
</tbody>
</table>
### Table 3. EEG characteristics of sleep stages.\textsuperscript{N7,N8}

<table>
<thead>
<tr>
<th>Patterns</th>
<th>EEG Characteristics</th>
<th>Stage(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontinuous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trace alternant (TA)\textsuperscript{N9,N10}</td>
<td>This EEG pattern in full-term infants is generally only seen in stage N sleep. It is characterized by at least 3 alternating runs of bilaterally symmetrical synchronous high voltage (50-150 µV) bursts of 1-3 Hz delta activity lasting 5-6 seconds (range 3-8 seconds) alternating with periods of lower amplitude (25-50 µV) 4-7 Hz theta activity (range 4-12 seconds).</td>
<td>N</td>
</tr>
</tbody>
</table>
# AASM Scoring Rules-Infant

<table>
<thead>
<tr>
<th>Continuous</th>
<th>Description</th>
<th>State(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low voltage irregular (LVI)</td>
<td>Continuous low voltage mixed-frequency activity with delta and predominantly theta activity.</td>
<td>R, Wake</td>
</tr>
<tr>
<td>High voltage slow (HVS) [^11]</td>
<td>Continuous synchronous symmetrical predominantly high voltage 1-3 Hz delta activity.</td>
<td>N, rarely R</td>
</tr>
<tr>
<td>Mixed (M)</td>
<td>Both high voltage slow and low voltage polyrhythmic components; these are intermingled with little periodicity. The amplitude is lower than seen in the HVS pattern.</td>
<td>Wake, R, rarely N</td>
</tr>
</tbody>
</table>

## Waveforms of interest

<table>
<thead>
<tr>
<th>Waveforms of interest</th>
<th>Description</th>
<th>State(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep spindles [^12,^13]</td>
<td>12 to 14 Hz, asynchronous, most prominent in midline central (CZ) and central derivations. Occur only in stage N sleep.</td>
<td>N</td>
</tr>
</tbody>
</table>
# AASM Scoring Rules-Infant-Summary

<table>
<thead>
<tr>
<th>Stage</th>
<th>Behavioral</th>
<th>Respiration</th>
<th>EEG</th>
<th>EOG</th>
<th>Chin EMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake</td>
<td>Eyes open, crying, feeding</td>
<td>Irregular</td>
<td>LVI or M</td>
<td>REMs, blinks, scanning eye movements</td>
<td>Present</td>
</tr>
<tr>
<td>N</td>
<td>Reduced movement relative to wake (Eyes closed, periodic sucking, occasional startle)</td>
<td>Regular</td>
<td>TA, HVS, sleep spindles, or M</td>
<td>Eyes closed with no EMs</td>
<td>Present or low</td>
</tr>
<tr>
<td>R</td>
<td>Eyes closed Small movements</td>
<td>Irregular</td>
<td>LVI or M (rarely HVS)</td>
<td>REMs or Eyes closed with no EMs&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Low, TMA may occur</td>
</tr>
</tbody>
</table>

LVI = low voltage irregular, M = mixed, TA = trace alternant, HVS = high voltage slow, REMs = rapid eye movements.
Tracé discontinu (TD). An infant of 24 weeks' gestational age at age 4 weeks with an intraventricular hemorrhage and left shoulder twitching. Periods of alternating high-voltage mixed frequencies and periods of voltage suppression are normal findings before 28-30 weeks' postconceptional age.

Koszer et al http://emedicine.medscape.com/article/1139599-overview#aw2aab6b4
Tracé alternant (TA). Un nourrisson de 42 semaines d'âge post-conceptionnel, né par césarienne, avec des scores d'Apgar de 4/4 et des mouvements de secousses des membres supérieurs et inférieurs. Le TA se manifeste avec des respiration régulière, des EMG à basse voltage et des mouvements oculaires minimaux. Les périodes d'atténuation de l'ondulation de basse tension peuvent se produire périodiquement pendant le sommeil paisible.

Koszer et al http://emedicine.medscape.com/article/1139599-overview#aw2aab6b4
Quiet Sleep

Quiet Sleep

Fig. 8. An EEG segment of a 41-week 1-day-old female that documents high-voltage slow quiet sleep. Regular respirations and the absence of rapid eye movements are noted.

Scher, M (2008) Ontogeny of EEG-sleep from neonatal through infancy periods
Scher, M (2008) Ontogeny of EEG-sleep from neonatal through infancy periods
## Summary of Sleep Related Changes

<table>
<thead>
<tr>
<th>Physiological Measure</th>
<th>Awake/Sleep State</th>
<th>Quiet Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Awake</td>
<td></td>
</tr>
<tr>
<td>EMG (chin)</td>
<td>Phasic and tonic</td>
<td>Tonic</td>
</tr>
<tr>
<td>Respiration</td>
<td>Irregular</td>
<td>Regular</td>
</tr>
<tr>
<td>Eye movements</td>
<td>Random or pursuits</td>
<td>Absent</td>
</tr>
<tr>
<td>Body movements</td>
<td>Facial, limbs, and body</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Active Sleep</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phasic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irregular</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rapid eye movements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sucking and irregular limb movements</td>
<td></td>
</tr>
</tbody>
</table>
Developmental Factors
Newborns-6 months

- **Sleep**
  - NB Require 16-18 hours/day; polyphasic, ~equal between night and day; expectation that child awakens
  - ~6 Months 14-16 hours/day; sleep fairly consolidated into night; fewer daytime naps
  - More sensitive to light/dark cues

- **Development**
  - Primarily met by caregiver

- **Communication**
  - Crying
  - Increased mobility

Vriend, et al., 2011; Johnson and Mindel, 2011
0-2 months
Pay particular attention to:
- the presence and type of eye movements,
- facial movements
- respiration (regular or irregular),
- sucking, crying, grimacing
- Suck-swallow incoordination
SIDS

- Sudden Infant Death Syndrome (SIDS) is defined as the sudden death of an infant less than 1 year of age that cannot be explained after a thorough investigation is conducted, including a complete autopsy, examination of the death scene, and review of the clinical history.

- SIDS is the leading cause of death among infants aged 1–12 months, and is the third leading cause overall of infant mortality in the United States.

- Although the overall rate of SIDS in the United States has declined by more than 50% since 1990, rates for non-Hispanic black and American Indian/Alaska Native infants remain disproportionately higher than the rest of the population.

- Reducing the risk of SIDS remains an important public health priority.

  CDC, 2014
Breakdown of Sudden Unexpected Infant Death by Cause, 2015

- Sudden infant death syndrome: 43%
- Unknown cause: 32%
- Accidental suffocation and strangulation in bed: 25%
Sudden Unexpected Infant Death
Safe Sleep/Safe Babies

- Place the baby to sleep on his back for every sleep.
- Place the baby to sleep on a firm sleep surface.
- Keep soft objects, loose bedding, or any objects that could increase the risk of entrapment, suffocation, or strangulation out of the crib.
- Place your baby to sleep in the same room where you sleep but not the same bed.
- Breastfeed as much and for as long as possible.
- Schedule and go to all well-child visits.
- Keep the baby away from smokers and places where people smoke.
Safe Sleep/Safe Babies

- Do not let the baby get too hot.
- Offer a pacifier at nap time and bedtime.
- Do not use home cardiorespiratory monitors to help reduce the risk of SIDS.
- Do not use products that claim to reduce the risk of SIDS.
Summary

- Infant sleep patterns develop over the course of the first year in a step-wise fashion
- Documentation is crucial during sleep studies
- SIDS is a leading cause of infant mortality
- Sleep onset and night-time awakenings are common
Older Infants/Toddlers

- 6-12 months/12-24 months
- TST slightly decreased ~13 hours per day
- 6-9 months, most are sleeping through the night
  - Night wakings are still common (50% waking at least once/week)
  - Night time bottles
- Naps continue, but are shorter
- Development
  - Develops attachment to caregiver---separation anxiety
  - May have learned to fall asleep with caregiver
- Communication
  - Increased mobility and verbalization
- ~20-30% develop BIC SOA

Vriend, et al., 2011; Johnson and Mindel, 2011
Early Childhood

- 2-6 Years
- Transition from crib to bed
- Sleep duration decreases
- Daytime napping decreases/eliminated (<10% 6 year old nap)
- 25-50% have sleep problems
- Increased mobility and language
- Development
  - Initiative and independence
  - Rewards/punishment

Vriend, et al., 2011; Johnson and Mindel, 2011
Middle Childhood

- 6-12 years
- Should be sleeping 9-10 hours per night
  - Highly energetic; EDS should be warning sign
  - Napping rare
  - Night Owl vs Lark emerge
- ~37% have a parent reported bedtime problem

Development
- Peer relationships more important
- More technology usage
- Possible increased social anxiety
- Increasing social and school obligations

Vriend, et al., 2011; Johnson and Mindel, 2011
Adolescence

- 12-18 years
- ~ 2 hour bedtime delay
  - Social factors
    - Electronics; work; friends and school activities
  - Biological
- Typically have insufficient sleep during the week; make up for this on weekend
- Increased use of caffeine or energy drinks
- Development
  - Decreased parental influence
  - Moodiness and conflicts-- autonomy

Vriend, et al., 2011; Johnson and Mindel, 2011
Key Fact

Between 15% and 30% of 2- to 5-year-old children experience regular difficulties falling asleep (i.e., bedtime problems) or sleeping through the night (i.e., night waking).

Turnbull, Reid and Morton, 2013; SLEEP
Sleep Problems-Year One

- 10-30% of children have a sleep problem
- Behavioral Insomnia
  - Sleep onset
  - Night waking
- Colic
Sleep Problems: Early Childhood

- Earlier and regular bedtimes (rituals) associated with longer sleep duration
- May have frequent nighttime waking's
  - Temperament; inability to self-soothe
- Exhibit Signs of sleep related breathing problems
Sleep Disorders

Socioeconomic and demographic factors
Age, gender, race/ethnicity, nativity/immigrant status, household structure, rural/urban residence and household socioeconomic status

Behavioral factors-proximate determinants
Physical inactivity, lack of sports participation, sedentary activities (TV viewing and recreational computer use), child overweight/obesity, secondhand smoke

Social, physical, and built environments
Neighborhood safety, deprivation, poor housing, vandalism, crime, urban design, recreational centers, modes of transportation, access to parks/playgrounds, sidewalks/walking paths, and green spaces

Sleep problems, inadequate sleep, and sleep duration

**Figure 1:** A simple model of neighborhood and sociobehavioral determinants of sleep problems in children and adolescents.
Autism and Sleep

- 1 in 68 children are on the autism spectrum
- Occurs in all racial, ethnic and social economic status
- 4.5 times more common among boys (CDC, retrieved March 5, 2017)
- 53% of children (2–5 years of age) with ASD have a sleep problem

Take Home Point
Sleep development may be different in ASD

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4770638/
Strategies to Improve Sleep in Children with Autism Spectrum Disorders: A Parent's Guide

Many children with ASD have difficulty with sleep. This can be stressful for children and their families. This informational booklet is designed to provide parents with strategies to improve sleep in their child affected by autism spectrum disorders (ASD). The suggestions in this tool kit are based on both research and clinical experience of sleep experts.

Download the Sleep Tool Kit (Parent Booklet) here!

https://www.autismspeaks.org/science/resources-programs/autism-treatment-network/tools-you-can-use/sleep-tool-kit
Summary

- First 2-3 months - EEG maturation
- Post 2 months, basically scoring the same as adults
- SUID is declining, important to know the safe sleep rules
- Sleep problems occur throughout childhood
- Many factors impact the sleep of children
- Autism spectrum is a growing problem and should be taken into consideration when assessing childhood sleep
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Robyn.wooldtke@gmail.com