Sleep Disorders and Testing

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Presentation Goals

- An overview of sleep
- Discuss the AASM criteria for sleep staging and scoring
- Discuss the diagnostic tools used in sleep medicine
Sleep

- Within sleep, two separate states have been defined on the basis of a constellation of physiologic parameters.

- These two states, non-rapid eye movement (NREM) and REM
Newborns enter REM sleep (called *active sleep*) before NREM (called *quiet sleep*) and have a shorter sleep cycle (approximately 50 minutes).

Sleep stages emerge as the brain matures during the first year.

At birth, active sleep is approximately 50% of total sleep and declines over the first year to approximately 30%.

REM sleep as a percentage of total sleep is approximately 20% to 25% across childhood, adolescence, adulthood, and into old age.

Slow wave sleep decreases across adolescence by 40% from preteen years.
Sleep Stages

- Stages of Sleep
  - Stage W (wakefulness)
  - Stage N1 (NREM1) *previous stage 1
  - Stage N2 (NREM2) *previously stage 2
  - Stage N3 (NREM3) *previously stage 3/4
  - Stage R (REM)

- Stages are scored in 30 second epochs
Distribution of sleep stages

- Stage 1 5%
- Stage 2 45-55%
- Stage 3&4 15-20%
- Stage REM 20-25%

Factors that alter sleep
- sleep-wake schedule
- phase of the circadian timing system
- drugs
- sleep disorders
Changes in sleep architecture related to aging include:

- Reduction in duration of SWS
- Increase in number and duration of nocturnal arousals
- A slight reduction in REM sleep
- All of the above
Changes in sleep with age

Time (in minutes) for sleep latency and wake time after sleep onset (WASO) and for rapid eye movement (REM) sleep and NREM sleep stages 1, 2, and slow wave sleep (SWS). Summary values are given for ages 5 to 85 years. (Ohayon M, Carskadon MA, Guilleminault C, et al: Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. Sleep 2004;27:1255-1273.)
Sleep disorders - Common concerns

- Insomnia - Sleep onset or sleep-maintenance
- Excessive daytime sleepiness
- Fatigue
- Snoring
- Unusual behaviors in sleep
Tools

- After complete history and physical examination
Epworth Sleepiness Scale

<table>
<thead>
<tr>
<th>Situation</th>
<th>Chance of dozing (0–3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting and reading</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Watching television</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Sitting inactive in a public place—for example, a theater or meeting</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>As a passenger in a car for an hour without a break</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Lying down to rest in the afternoon</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Sitting and talking to someone</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Sitting quietly after lunch (when you’ve had no alcohol)</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>In a car, while stopped in traffic</td>
<td>0 1 2 3</td>
</tr>
</tbody>
</table>

**Total Score**

Scale ranges from 0-24
Daytime sleepiness > 10

0 = would never doze 1 = slight chance of dozing 2 = moderate chance of dozing 3 = high chance of dozing

Ages and ESS scores

Subjects/Diagnoses

- Healthy control subjects
- Primary snoring
- Obstructive sleep apnea syndrome
- Narcolepsy
- Idiopathic hypersomnia
- Insomnia
- Periodic limb movement disorder

<table>
<thead>
<tr>
<th>Total number</th>
<th>Score (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 (14/16)</td>
<td>5.9 ± 2.2</td>
</tr>
<tr>
<td>32 (29/3)</td>
<td>6.5 ± 3.0</td>
</tr>
<tr>
<td>55 (53/2)</td>
<td>11.7 ± 4.6</td>
</tr>
<tr>
<td>13 (8/5)</td>
<td>17.5 ± 3.5</td>
</tr>
<tr>
<td>14 (8/6)</td>
<td>17.9 ± 3.1</td>
</tr>
<tr>
<td>16 (6/12)</td>
<td>2.2 ± 2.0</td>
</tr>
<tr>
<td>18 (16/2)</td>
<td>9.2 ± 4.0</td>
</tr>
</tbody>
</table>

## Sleep Log

### SLEEP LOG: Use these symbols

- ●: Lights out or in bed trying to sleep
- •: Asleep
- ○: Lights on or out of bed for the night
- C: Caffeinated coffee or soda

### Example

<table>
<thead>
<tr>
<th>PM</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Noon</td>
<td>11</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

- **Case #4**

<table>
<thead>
<tr>
<th>Day Date</th>
<th>How much sleep?</th>
<th>Sleeping aid, alcohol, medicine?</th>
<th>Sleep Quality?</th>
<th>Daytime Fatigue?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri 7/1</td>
<td>6+ 1 hour nap.</td>
<td>6:30 pm 1 beer, 10pm Halcion, 25 mg</td>
<td>Hi Med Lo</td>
<td>Lo Med Lo</td>
</tr>
</tbody>
</table>

### Fill out in the morning

<table>
<thead>
<tr>
<th>Day Date</th>
<th>How much sleep?</th>
<th>Sleeping aid, alcohol, medicine?</th>
<th>Sleep Quality?</th>
<th>Daytime Fatigue?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon.</td>
<td>5.5 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Tues.</td>
<td>6.0 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Weds.</td>
<td>5.5 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Thurs.</td>
<td>6.0 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Fri.</td>
<td>9 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Sat.</td>
<td>9.5 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
<tr>
<td>Sun.</td>
<td>4 hrs.</td>
<td>None</td>
<td>Hi Med Lo</td>
<td>Hi Med Lo</td>
</tr>
</tbody>
</table>

### Fill out in the evening

**FIGURE C4-1**

Sleep log.

Spielman & Glovinsky, NY 1994
Polysomnography: Overnight sleep study to evaluate and quantify overall sleep architecture, breathing, leg movements, abnormal behaviors.

- Sleep apnea
- Periodic limb movements
- Parasomnias (includes video-EEG)
- Document normal sleep before multiple sleep latency test
- Not usually indicated for insomnia
Polysomnography

- EEG
- EMG
- Respiratory monitoring
- Snoring
- Oxygen saturation
- EKG
- Extended video-EEG
- Position monitoring
An ‘epoch’ of a PSG is a 30-second page or screen of data. This is the basic unit or page used for analyzing and reporting PSG data.

- The paper speed for a 30 second epoch is 10 mm/second.
- The impedance of any electrode pair should not exceed 10 kohm.
EEG

- A minimum pen deflection of 7.5-10 mm for 50 microvolts is recommended.
- Frequency of Delta: < 4 Hz
- Frequency of Theta: 4 < 8 Hz
- Frequency of Alpha: 8-13 Hz
- Frequency Beta: >13 Hz
Filters - The frequency at which response to a sine wave input has decreased to 70% of its initial amplitude.

- High Frequency Filter (low band pass filter) - 35 Hz
- Low Frequency Filter (high band pass filter) - 0.3 Hz
Question 2

Which of the following is most attenuated by a high pass filter of 5 Hz

- 5 Hz
- 10 Hz
- 3 Hz
- Sleep Spindles
Which of the following is **most** attenuated by a low pass filter of 15 Hz

- Delta frequency
- K-complexes
- Theta activity
- Sleep Spindles
EEG Recommended Derivations

- $F_4 - M_1$
- $C_4 - M_1$
- $O_2 - M_1$
- Backup electrodes at $F_3, C_3, O_1$ and $M_2$ in case of malfunction
- Minimum of 3 EEG derivations recommended
Stage -----
Stage ---
**K-complexes**

- Well-delineated negative sharp wave immediately followed by a positive component standing out from background.
- Duration ≥0.5 sec, Maximal amplitude in frontal leads
- Associated arousal: must occur within 1 second after K complex
Spindles

- Train of distinct waves with frequency of 11-16 Hz with duration of ≥0.5 seconds. Maximal amplitude in central leads
Stage ---
Stage N₃

- Score stage N₃ when 20% or more of epoch consists of slow wave activity, irrespective of age.
  - Slow wave frequency of 0.5 Hz-2 Hz and peak to peak amplitude of >75 µV, measured in frontal regions.
  - Sleep spindles may persist in stage N₃.
  - Eye movements are not typically seen.
NREM sleep

- Sympathetic tone is typically decreased during NREM sleep, but during arousal sympathetic tone increases in bursts of activity.
- Systemic B.P falls by 10% during NREM sleep, but fluctuates during REM sleep.
Stage ---
Stage R (REM)

- Score stage R in epochs with all of the following
  - Low chin EMG tone
  - Rapid eye movements
  - Low amplitude mixed frequency EEG

- Saw-tooth waves seen during REM sleep have theta frequency and are prominent in the central leads.
REM Sleep

- Initial REM approximately 90-110 minutes after sleep onset
- 4-6 REM periods/night
A shortened REM latency can be seen in:

- Depression
- Narcolepsy
- Withdrawal from REM suppressing medications- antidepressants, alcohol
- CPAP titration
- All of the above
Score arousal in stages N1, N2, N3 or R if:

- Abrupt shift of EEG frequency including alpha, theta, and or frequencies >16 Hz (excluding spindles)
- Duration: at least 3 seconds
- 10 seconds of stable sleep must precede the change
- Arousals in REM require a concurrent increased in chin EMG lasting at least 1 second.
Cardiac Rules

- Sinus tachycardia
- Bradycardia
- Asystole
- Wide complex tachycardia
- Narrow complex tachycardia
- Atrial fibrillation
PSG with extended-EEG

### For a 12-Channel Study

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fp1 = C3</td>
</tr>
<tr>
<td>2.</td>
<td>C3 = O1</td>
</tr>
<tr>
<td>3.</td>
<td>Fp2 = C4</td>
</tr>
<tr>
<td>4.</td>
<td>C4 = O2</td>
</tr>
<tr>
<td>5.</td>
<td>Fp1 = T3</td>
</tr>
<tr>
<td>6.</td>
<td>T3 = O1</td>
</tr>
<tr>
<td>7.</td>
<td>Fp2 = T4</td>
</tr>
<tr>
<td>8.</td>
<td>T4 = O2</td>
</tr>
<tr>
<td>9.</td>
<td>EMG - submentalis-mentalis</td>
</tr>
<tr>
<td>10.</td>
<td>Right outer canthus - left outer canthus</td>
</tr>
<tr>
<td>11.</td>
<td>Nasal-oral airflow</td>
</tr>
<tr>
<td>12.</td>
<td>ECG</td>
</tr>
</tbody>
</table>

### For a 21-Channel Study

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fp1 = F3</td>
</tr>
<tr>
<td>2.</td>
<td>F3 = C3</td>
</tr>
<tr>
<td>3.</td>
<td>C3 = P3</td>
</tr>
<tr>
<td>4.</td>
<td>P3 = O1</td>
</tr>
<tr>
<td>5.</td>
<td>Fp2 = F4</td>
</tr>
<tr>
<td>6.</td>
<td>F4 = C4</td>
</tr>
<tr>
<td>7.</td>
<td>C4 = P4</td>
</tr>
<tr>
<td>8.</td>
<td>P4 = O2</td>
</tr>
<tr>
<td>9.</td>
<td>Fp1 = F7</td>
</tr>
<tr>
<td>10.</td>
<td>F7 = T3</td>
</tr>
<tr>
<td>11.</td>
<td>T3 = T5</td>
</tr>
<tr>
<td>12.</td>
<td>T5 = O1</td>
</tr>
<tr>
<td>13.</td>
<td>Fp2 = F8</td>
</tr>
<tr>
<td>14.</td>
<td>F8 = T4</td>
</tr>
<tr>
<td>15.</td>
<td>T4 = T6</td>
</tr>
<tr>
<td>16.</td>
<td>T6 = O2</td>
</tr>
<tr>
<td>17.</td>
<td>EMG mentalis - submentalis</td>
</tr>
<tr>
<td>18.</td>
<td>Right outer canthus/A1</td>
</tr>
<tr>
<td>19.</td>
<td>Left outer canthus/A2</td>
</tr>
<tr>
<td>20.</td>
<td>Nasal-oral airflow</td>
</tr>
<tr>
<td>21.</td>
<td>ECG</td>
</tr>
</tbody>
</table>
Electrodes placed beneath the chin, overlying the mentalis/submentalis muscles.

Leg muscle activity: anterior tibialis muscle.

Bruxism: masseter
EMG- Periodic leg movement disorder
PLMs-Definition

- PLMs occur in series of at least 4 movements, each movement generating an EMG potential lasting 0.5-10 seconds with a 5-90 second interval between movements.
- Minimum amplitude of the EMG potential is an 8 microvolt increase in EMG voltage above resting EMG contraction of the Anterior Tibialis muscle.
PLMs

- PLM index >15/hour considered significant in adults
- PLM index >5/hour considered significant in kids
RLS Symptoms-IRLSSG

- Urges to move the limbs, accompanied by uncomfortable and unpleasant feelings in the limbs.
- Rest or inactivity precipitates or worsens symptoms.
- Getting up or moving improves the sensation.
- Evening or nighttime appearance or worsening of symptoms.
All patients with RLS also have periodic limb movements of sleep.

- True
- False
Parasomnia characterized by vigorous movements related to increased tonic and/or phasic EMG activity during REM sleep.

Chronic RBD can be idiopathic or secondary to neurodegenerative diseases affecting the brainstem.

Patients with MSA, PD, or DLB were more likely to have probable and PSG-confirmed RBD compared to subjects with the nonsynucleinopathies (probable RBD 77/120=64% vs. 7/278 = 3%)

Electrooculography

- Essential for the documentation of rapid eye movements characteristic of REM sleep.
- Sleep onset often occurs in association with slow eye movements (SEM’s).
- Electrical potential differences between the front and back of the eye are responsible for the generated electrical fields.
Electrocululogram (EOG)

- **Recommended**
  - $E_1 - M_2$
  - $E_2 - M_2$
- **Alternative**
  - $E_1 - F_{pz}$
  - $E_2 - F_{pz}$
  - Vertical: in-phase deflections
  - Horizontal: out-of-phase deflections
Electrocululogram (EOG)

- **Recommended**
  - $E_1-M_2$
  - $E_2-M_2$

- **Alternative**
  - $E_1-F_{pz}$
  - $E_2-F_{pz}$
  - Vertical: in-phase deflections
  - Horizontal: out-of-phase deflections
Evaluation of Ventilation

- Nasal pressure (nasal cannula with pressure transducer)
- Airflow-Thermistor or thermocouple
- Pneumotachography (PNT)
- Respiratory inductive plethysmography (RIP)
- Peripheral end-tidal CO₂ (PETCO₂)
- Esophageal pressure (Pes)
- Oximetry
- Arousals
Nasal Pressure Transducer
Obstructive Sleep Apnea

AHI Classification of severity

< 5 Normal
5-15 Mild
15-30 Moderate
>30 Severe

AHI: Apnea-hypopnea index

Pediatric criteria
AHI >1/hour
Score an obstructive apnea if there is a ≥90% drop in amplitude of the airflow sensor lasting at least 10 seconds.

Score an obstructive hypopnea if the nasal pressure signal changes ≥30% lasting >10 seconds with either a >3% desaturation or associated with an arousal.
OSA management with CPAP and REM rebound
OSA management with BPAP
Complex Sleep Apnea
- Adaptive Servo-Ventilation Settings
  - EPAP min
  - EPAP max
  - PS min
  - PS max
  - Max pressure
  - Back up rate
PM for the diagnosis of OSA should be performed only in conjunction with a comprehensive sleep evaluation.

May be used as an alternative to polysomnography (PSG) for the diagnosis of OSA in patients with a high pretest probability of moderate to severe OSA.

PM is not appropriate for the diagnosis of OSA in patients with significant comorbid medical conditions that may degrade the accuracy of PM, including, but not limited to, moderate to severe pulmonary disease, neuromuscular disease, or congestive heart failure.

J Clin Sleep Med 2007;3(7):737-747
Portable Monitoring
Insufficient Sleep
- Short sleep latency
- Increased sleep efficiency
- Decreased stage 1 sleep
- Increased SWS and REM sleep

Narcolepsy
- Increased arousals
- Short REM latency

Obstructive Sleep Apnea
- Obstructive apneas-hypopneas
- Low minimum oxygen desaturations
- Increased stage 1 sleep with arousals

Periodic Leg movements of sleep
- Frequent leg movements
Subjects are given 4-5 naps (chances to fall asleep) 2 hours after waking.

Subjects should be free of REM-altering medications.

Mean sleep latency (average time taken to fall asleep) and REM sleep (whether subject goes into REM during a nap) are determined.
**MSLT**: Mean Sleep latency: 1.8 minutes; SOREM’s: 5/5 naps
Multiple Sleep Latency Test (MSLT)

Mean sleep latency (in minutes)

- **≤ 8** - consistent with hypersomnia
- **10-12** - normal
- **8-10** - ‘grey’ zone

Affected by duration of sleep on the previous night, medications, age
Narcolepsy with Cataplexy

- Most commonly caused by a loss of Hypocretin (Hcrt)-1 producing cells in the hypothalamus.

- Approximately 90% have significantly decreased CSF hypocretin-1 levels.

- HLA-DQB1*0602 - most common HLA marker associated with narcolepsy, but is not sufficient to cause narcolepsy. Additional gene(s) or environmental factors play a role.

- Hcrt system sends strong excitatory projections to monoaminergic cells. Loss of Hcrt creates a cholinergic-monoaminergic imbalance in narcolepsy.
**Maintenance of Wakefulness Test (MWT)**

- This tests the patient's ability to remain awake in a comfortable sitting position in a dark room.
- Four-trial MWT 40 minute protocol at 2-hour intervals is recommended by the AASM practice parameters.
- Measures the ability to stay awake.
- Most normal persons without excessive sleepiness remain awake during these ‘naps’.
- Control mean latency 30.4 +/- 11.20 min
- Mean latency < 8 minutes on a 40 minute nap is considered abnormal.
## Other Tests for Narcolepsy

<table>
<thead>
<tr>
<th>Test</th>
<th>Narcolepsy with Cataplexy</th>
<th>Narcolepsy without Cataplexy</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLA DQB1*0602</td>
<td>&gt;80% sensitive</td>
<td>60% sensitive, not specific (8-38% of gen. pop. tests +)</td>
</tr>
<tr>
<td>CSF hypocretin deficiency (&lt;110 pg/ml)</td>
<td>90% sensitive, 99% specific</td>
<td>16% sensitive, 99% specific</td>
</tr>
</tbody>
</table>
Actigraphy-Actiwatches are small, rugged, actigraphy-based data loggers that record a digitally integrated measure of gross motor activity.
Actigraphy

- Measure of activity over time.
- Activity equates with the sleep wake cycle.
- Low activity occurs during the night and greater activity during wakefulness.
- Can provide useful objective data in diagnosis of certain circadian rhythm disorders and insomnia.
Phase typing for Circadian Rhythm Disorders

- Melatonin rhythm is the most accurate measure because it is masked only by light exposure.
- Blood, saliva or urine should be sampled under dim light.
- Measure the onset in the evening, with sampling every 30 minutes. This is called dim light Melatonin onset (DLMO).
- Useful in determining the timing of the light exposure or melatonin dose in patient with circadian rhythm disorders.
Practice Parameters in Sleep Medicine

- Practice parameters and reviews, published in Sleep by the Standards of Practice Committee of the American Academy of Sleep Medicine, are available at http://www.aasmnet.org/PracticeParam.aspx. Examples include:
  - Clinical Use of the Multiple Sleep Latency Test and the Maintenance of Wakefulness Test
    Published January 2005
  - Dopaminergic Treatment of Restless Legs Syndrome and Periodic Limb Movement Disorder
    Published May 2004
  - Use of Portable Monitoring Devices in the Investigation of Suspected Obstructive Sleep Apnea in Adults
    Published November 2003
  - Using Polysomnography to Evaluate Insomnia: An Update
    Published September 2003
  - The Role of Actigraphy in the Study of Sleep and Circadian Rhythms
    Published May 2003
  - Use of Auto-Titrating Continuous Positive Airway Pressure Devices for Titrating Pressures and Treating Adult Patients with Obstructive Sleep Apnea Syndrome
    Published March 2002
  - Use of Laser-Assisted Uvulopalatoplasty (Update-2000)
    Published August 2001
  - Treatment of Narcolepsy: An Update for 2000
    Published June 2001
  - Evaluation of Chronic Insomnia
    Published March 2000
  - Nonpharmacologic Treatment of Chronic Insomnia
    Published December 1999
  - Use of Light Therapy in the Treatment of Sleep Disorders
    Published August 1999
  - Indications for Polysomnography and Related Procedures
    Published September 1997
  - Treatment of Obstructive Sleep Apnea in Adults: The Efficacy of Surgical Modifications of the Upper Airway
    Published March 1996
  - Treatment of Snoring and Obstructive Sleep Apnea with Oral Appliances
    Published September 1995
  - Use of Laser-Assisted Uvulopalatoplasty
    Published December 1994
  - Use of Stimulants in the Treatment of Narcolepsy
    Published June 1994