Relevant financial relationships with a commercial interest:

- Jazz Pharmaceuticals: Research Grant (current)
- Invado Pharmaceuticals: Research Grant (current)
- Ikaria Pharmaceuticals: Consultant (past)
Learning Objectives

• Learn the basics of sleep staging
• Identify common sources of artifacts
• Identify the impact of medications on sleep staging
• Learn about the special nuances for scoring respiratory events
Sleep Stages

• AASM scoring manual for sleep was introduced in 2007

• Sleep staging is done with 3 standard EEG derivations; frontal, central and occipital

• Sleep stages include NREM stages N1, N2 and N3 and Stage R (REM)

• Individual epochs are scored based on the stage of sleep seen in the majority of the epoch
• Alpha rhythm (8-13 Hz) in > 50% of epoch with eye closure and/or

• Eye blinks, rapid eye movements with normal or high chin tone, reading eye movements, slow eye movements

Epoch courtesy of Medical University of South Carolina Sleep Center
Begin scoring N1 when:

- > 50% of epoch contains low amplitude (4-7 Hz), mixed frequency (LAMF) EEG waves and/or

- Presence of any of the following
  - Vertex sharp waves
  - Slow eye movements
Characteristics:
- Background LAMF activity associated with K complexes and/or sleep spindles
- Begin scoring N2 if K complexes are unassociated with arousals or sleep spindles are present during 1st half of the epoch or during the 2nd half of the previous epoch
Continuation of Stage N2

Continue to score N2 in epochs with LAMF without K complexes or sleep spindles if preceded by an N2 epoch without an intervening arousal.
End of Stage N2

- Transition to W or another sleep stage
- Arousal followed by LAMF (stage as N1 if criteria for R are not met)
- Major body movement followed by slow eye movements and LAMF (N1)
Stage N3

- Characterized by slow wave activity (0.5-2 Hz and peak-to-peak amplitude ≥ 75 uV)

- Stage epoch as N3 if slow wave activity ≥ 20% of epoch (AASM recommended)

Epoch courtesy of Medical University of South Carolina Sleep Center
Stage R

Stage R is scored when ALL of the following are present:

- LAMF EEG without sleep spindles or K complexes
- Low chin tone > 50% of epoch and
- Rapid eye movements at any position within the epoch
In the absence of REMs, score sleep epochs preceding and contiguous with definite stage R as R if:

- EEG shows LAMF without K or sleep spindles
- Chin tone is low
- No intervening arousal occurs
- Slow eye movements following arousal or stage W are absent
- Stage R rules take precedence over N2 rules
When staging a polysomnogram, which of the following features are part of the definition to designate a 30 second epoch of sleep as REM sleep?

A. Eye blinks occurring at a frequency of 0.5 – 2 Hz
B. Slow rolling eye movements
C. Low chin electromyogram (EMG) tone relative to other stages of sleep for the majority of the epoch
D. One or more K-complexes
E. Electroencephalogram (EEG) activity with a frequency of 0.5-2 Hz
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E. Electroencephalogram (EEG) activity with a frequency of 0.5-2 Hz
• Benzodiazepines increase sleep spindles and thus N2 sleep and reduce N1 and N3 sleep (1)

• Drug induced spindles are associated with increased spindle density (2)

• Non-benzodiazepine GABA receptor agonists i.e. zolpidem, zaleplon and eszopiclone also increase sleep spindles, but do not affect N3 sleep (2)

(1) Hirshkowitz M et al, Sleep 1982
(2) Wamsley EJ et al, Sleep, September 1, 2013
• All antidepressants with the exception of Bupropion, Mirtazapine, and Nefazodone prolong REM latency

• SSRIs increase eye movements in all stages of sleep

• Atypical antipsychotics such as Olanzapine suppress REM sleep and increase N3 sleep

(1) Hirshkowitz M et al, Sleep 1982
(2) Wamsley EJ et al, Sleep, September 1, 2013
Electrode Popping Artifact:

• Pulling of an electrode away from the skin, resulting in abrupt impedance change

• Sudden, single or multiple deflections which do not modify background EEG activity and are limited to the affected electrode

• Corrected by applying electrode gel, replacing the affected electrode or switching to an alternative derivation
Sweat/Sway artifact: very low frequency oscillations due to sweating

60 Hz artifact: results from increased impedance between an active electrode and the ground of the amplifier

EKG artifact: sharp artifact waves due to EKG interference that correspond to the QRS complex on the electrocardiographic tracing.
Cardio-ballistic artifact:

- Small “pulse” waves which occur synchronously with heartbeat and the electrocardiogram tracing.
- Occur due to displacement of air from the intra-thoracic cavity by heartbeats.
- May affect airflow, chest, and abdominal leads.
- Oscillations may occur irrespective of airway patency.
Apnea

Defined by:

- Drop in airflow by $\geq 90\%$ on oronasal thermistor or PAP flow device

  AND

- Duration of decreased airflow $\geq 10$ seconds

Figure 1. A respiratory event that should be scored as an apnea. The red bracket indicates the full duration of the apnea event.
# Apneas

## Type of Apnea

<table>
<thead>
<tr>
<th></th>
<th>CENTRAL</th>
<th>OBSTRUCTIVE</th>
<th>MIXED</th>
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<tbody>
<tr>
<td>Airflow</td>
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<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
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<tr>
<td>Diaphragmatic Excursions</td>
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<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
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<tr>
<td>Arterial Oxygen Saturation ($S_aO_2$)</td>
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<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
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The latest AASM scoring guidelines provide a recommended definition of hypopneas that require at least 30% drop in airflow for at least 10 seconds accompanied by an oxygen desaturation of at least 3% or an arousal. This updated definition has been recently shown to result in which of the following?

A. Decreased scoring of hypopneas and resultant decrease in diagnosis of obstructive sleep apnea (OSA)
B. Increase scoring of hypopneas and resultant increase in diagnosis of OSA
C. Increased challenge in deciding which patient with mild asymptomatic OSA should be treated
D. Increased scoring of respiratory-effort arousals (RERAs) and resultant increase in diagnosis of OSA
E. B and C
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E. **B and C**
Definition of Hypopnea

**Recommended**
- Peak airflow drop $\geq 30\%$
on nasal pressure/PAP flow device
- Duration $\geq 10$ seconds
- Desaturation $\geq 3\%$ or arousal

**Acceptable**
- Peak airflow drop $\geq 30\%$
- Duration $\geq 10$ seconds
- Desaturation $\geq 4\%$
Scoring Hypopneas

- 3% and 4% desaturation criteria have been found to be equivalent in predicting adverse outcomes\(^1\)

- \(> 3\%\) desaturation has been associated with atrial and ventricular arrhythmias\(^2\), stroke\(^3\) and fasting hyperglycemia\(^4\)

- Arousals were added to the hypopnea definition as they cause fragmented sleep resulting in daytime sleepiness which can be reversed with CPAP\(^5\)

- Arousals have also been associated with hypertension likely as a result of the associated sympathetic activation\(^6\)

- Scoring of hypopneas with \(\geq 3\%\) desaturation and/or arousal as opposed to 4% desaturation results in a substantial increase in the AHI\(^7,8\)

3. Am J Respir Crit Care Med 2010;182:269-77  
4. Sleep 2008;31:1018-2  
6. Chest 199;:655-659  
7. Am J Respir Crit Care Med 2000;161:369-75  
Respiratory Effort Related Arousals

Arousal preceded by

- Increased respiratory effort or flattening of inspiratory part of nasal pressure/PAP flow waveform lasting > 10 seconds

- Does not meet criteria for apnea or hypopnea
A 32 year old obese male presents with loud snoring and non-refreshed sleep. He denies ever being told of witnessed apnea or waking up gasping. His ESS is 11. He undergoes overnight polysomnography and the following respiratory pattern is seen.

The event seen in the above figure is which of the following?
A. Obstructive Apnea
B. Central Apnea
C. Mixed Apnea
D. Obstructive Hypopnea
E. Normal respiratory flow pattern
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A. Obstructive Apnea  
B. Central Apnea  
C. Mixed Apnea  
D. **Obstructive Hypopnea**  
E. Normal respiratory flow pattern
Cheyne-Stokes Breathing

- ≥ 3 consecutive central apneas and/or central hypopneas separated by a crescendo-decrescendo change in breathing amplitude, with a cycle length of > 40 seconds (1)

  AND

- Central apnea index ≥ 5/hour associated with crescendo/decrescendo breathing over ≥ 2 hours of recording

- Longer hyperpneas indicate longer circulation time and a lower cardiac output (2)

(1) AASM scoring manual version 2.2
A 50 y/o male patient treated with fluoxetine for depression complains of excessive daytime sleepiness. His sleep study is negative for sleep disordered breathing.

What abnormality is shown in this epoch?

A. Restless Leg Syndrome
B. 60 Hz artifact
C. Periodic limb movements in sleep
D. Sleep-related seizures
E. Obstructive apneas
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C. Periodic limb movements in sleep
D. Sleep-related seizures
E. Obstructive apneas
Periodic Limb Movements in Sleep

- Rhythmic stereotypic limb movements characterized by extension of great toe and flexion of ankle, knee and hip

- AASM definition of limb movements (LM):
  - Duration 0.5-10 seconds
  - ≥ 8 µV increase above resting EMG
  - Onset is defined by the 8 µV increase in EMG voltage above resting EMG
  - End is defined by EMG < 2 µV above resting EMG for at least 0.5 seconds
Periodic Limb Movement Series

• AASM definition of periodic limb movement series:
  – ≥ 4 consecutive limb movements
  – Period between LMs is 5-90 seconds
  – LMs in 2 different legs separated by < 5 seconds are counted as a single LM
Key Points

• Sleep stages include NREM stages N1, N2, N3, and stage R (REM)

• Sleep architecture changes with adoption of AASM scoring rules include increase in N3 sleep and decrease in N2 sleep time

• The AASM recommended definition of hypopnea includes a ≥ 3% drop in oxygen saturation or arousal, while the alternative definition includes a ≥ 4% decrease in oxygen saturation after the event
Key Points

• The recommended definition of hypopnea has recently been shown to increase the prevalence of OSA

• Common artifacts must be identified and corrected to ensure accurate interpretation of polysomnograms