Sleep: Introduction and Physiology

Chitra Lal, MD, D-ABSM, FACP, FAASM, FCCP
Assistant Professor of Medicine, Pulmonary, Critical Care and Sleep, MUSC
Basics

• Sleep is a naturally recurring state characterized by:
  - Reduced or absent consciousness
  - Relatively suspended sensory activity
  - Inactivity of nearly all voluntary muscles
  - Decreased ability to react to stimuli
  - Easily reversible
Functions of Sleep

- **Energy Conservation**: decrease in metabolic rate and body temperature
- **Restoration and Recovery**: increased anabolic hormones, decreased catabolic hormones
- **Ecological Hypotheses**: of predator avoidance
- **Memory**: Reinforcement and consolidation
- **Synaptic and Neuronal Network Integrity**
Body Rhythms

- Ultradian
- Circadian: Zeitgebers or timegivers like daylight
- Infraadian
- Circannual
Circadian Rhythms in Humans

- 12:00 Noon: Highest Alertness
- 10:00 A.M.: Melatonin Secretion Stops
- 7:30 A.M.: Sharpest Blood Pressure Rise
- 6:45 A.M.: Sharpest Blood Pressure Rise
- 6 A.M.: Lowest Body Temperature
- 2:00 A.M.: Deepest Sleep
- 4:30 A.M.: Highest Body Temperature
- 6:30 P.M.: Highest Blood Pressure
- 5:00 P.M.: Greatest Cardiovascular Efficiency and Muscle Strength
- 3:30 P.M.: Fastest Reaction Time
- 2:30 P.M.: Best Coordination
- 6 P.M.: Circadian Rhythm
- 9:00 P.M.: Melatonin Secretion Starts
- 7:00 P.M.: Highest Body Temperature
- Midnight: 12:00
Circadian Rhythm:

24 hour - sleep / dream cycle

- 12 pm Noon: Awake
- 9 am: Deep Sleep
- 6 am: REM Dreaming Sleep
- 3 am: REM Dreaming Sleep
- Midnight: REM Dreaming Sleep

Note: This chart is based on a normal 8 hour night of sleep with a 90 minute Ultradian Rhythm.

www.LucidDreamExplorers.com/dreamscience
Two Process Model

• Process S or homeostatic drive to sleep

• Process C or wake promoting circadian rhythm
Normal circadian sleep rhythm. Sleep urge is greatest at night with a small increase at midday. Sleep need increases throughout the waking hours and is replenished during sleep.
Stages of Sleep

- REM sleep: increased brain activity, vivid dreams, 20%-25% of TST
  - Phasic REM sleep
  - Tonic REM sleep
- NREM sleep: reduced neuronal activity, 75%-80% of TST
  - N1, N2, N3
Sleep Architecture

• NREM followed by REM sleep every 90-120 minutes in adults
• REM cycles become longer with more pronounced eye movements in the later part of the night
Changes in Sleep with age
Sleep Hypnogram in a young adult
Characteristics of REM Sleep

- Relatively low voltage, mixed frequency EEG
- Saw-tooth waves on EEG
- Rapid eye movements
- Lowest chin tone (muscle atonia except in diaphragm and extraocular muscles)
- **Tonic REM sleep**: depression of monosynaptic and polysynaptic reflexes, hypotonia/tonic of major muscle groups, desynchronized EEG
Characteristics of REM Sleep

• Phasic REM sleep:
  - Bursts of REM
  - Myoclonic twitching of facial and limb muscles
  - Irregularities of HR and respiration
  - Variable BP
  - Spontaneous activity of middle ear muscles and tongue movements
Characteristics of NREM Sleep

- N1: theta waves, vertex waves, slow-rolling eye movements, 3%-8% of TST
- N2: spindles, K-complexes, 45%-55% of TST
- N3 (slow-wave sleep): delta waves > 20% of the epoch, 15%-20% of TST
Wake State

• Quiet wakefulness (closed eyes) : alpha rhythm and slow-rolling eye movements
• Awake and alert state (eyes open) : beta rhythm and sharp blinking eye movements
Brain waves

- Alpha rhythm: 8-13 Hz
- Beta rhythm: 13-21 Hz
- Theta rhythm: 4-7 Hz
- Sleep spindles: 12-14 Hz, 0.5-1.5 seconds in duration, waxing and waning morphology
- K complex: sharp “negative” and slow “positive” wave
- Delta waves: 0.5-3 Hz, > 75 mv in amplitude from peak to trough
Sleep Spindle

K-Complex
Sleep Stages

Stage 1
Theta Waves

Stage 2
Light Sleep

Stage 3 & 4
Delta Waves

REM Sleep
### Physiological Changes in Sleep

<table>
<thead>
<tr>
<th>Physiologic Process</th>
<th>NREM Sleep (compared to wake)</th>
<th>REM Sleep (compared to NREM)</th>
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</thead>
<tbody>
<tr>
<td>Brain activity</td>
<td>↓</td>
<td>Increases in motor and sensory areas</td>
</tr>
<tr>
<td>Heart rate</td>
<td>↓</td>
<td>↑ and variable</td>
</tr>
<tr>
<td>Blood Pressure</td>
<td>↓</td>
<td>↑ upto 30% and variable</td>
</tr>
<tr>
<td>Sympathetic nerve activity</td>
<td>↓</td>
<td>↑ from wake</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>Similar to wake</td>
<td>Absent</td>
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<tr>
<td>Blood flow to brain</td>
<td>↓</td>
<td>↑</td>
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<tr>
<td>Respiration</td>
<td>↓</td>
<td>↑ and variable</td>
</tr>
<tr>
<td>Airway Resistance</td>
<td>↑</td>
<td>↑ and variable</td>
</tr>
</tbody>
</table>
Physiology of Sleep

• Cardiovascular system:
  - ↑ in BP and HR with K complexes, arousals and body movements
  - ↑ risk of myocardial infarction in the morning

• REM sleep is a parasympathetic state with sympathetic surges during phasic REM sleep
Ventilation changes with sleep onset

- Wakefulness ↓ RAS
- ↑ Airway resistance
- Ventilation ↓ 0.5–1.5 l/min
- Metabolic rate ↓ 10–15%
- Chemosensitivity ↓ 20–25%

- ↑ Paco₂ 2–8 mm Hg
- ↓ PaO₂ 3–10 mmHg
- ↓ SaO₂ ~2%
Effects of Sleep on Ventilation

↓ cough reflex

↓ arousal response

↓ hypoxic ventilatory response

↓ pharyngeal muscle tone

Generalized hypotonia in REM sleep

Nocturnal Hypoventilation

Obstructive sleep apnea
Hormonal Changes in Sleep

Graph showing the percent of 24-hour mean levels of Growth Hormone and Prolactin over time, with peak levels during sleep time.
Effects of Sleep deprivation

- Irritability
- Cognitive impairment
- Memory lapses or loss
- Impaired moral judgement
- Severe yawning
- Hallucinations
- Symptoms similar to ADHD
- Impaired immune system
- Increased heart rate variability
- Risk of heart disease
- Increased reaction time
- Decreased accuracy
- Tremors
- Aches

Other:
- Growth suppression
- Risk of obesity
- Decreased temperature
- Risk of diabetes Type 2
ICSD-2

• Insomnia
• Sleep related breathing disorders
• Hypersomnias of central origin
• Circadian rhythm sleep disorders
• Parasomnias
• Sleep related movement disorders
• Isolated symptoms and normal variants
• Other sleep disorders