Conflicts

• Patents
  – ECG cardiopulmonary coupling (MyCardio LLC)
  – Positive Airway Pressure Gas Modulator
  – Auto CPAP algorithm (DeVilbiss-Drive)

• Consulting: GLG Councils, Jazz Pharmaceuticals

• Grants: DeVilbiss-Drive, Jazz Pharmaceuticals, American Sleep Medicine Foundation, NHLBI, NINDS
Sleep is a Biological Imperative

Multi-system effects of sleep

• Brain “housekeeping”
  – Attention, executive function, memory, affective regulation

• Cardiovascular and autonomic resetting

• Metabolic regulation
  – Appetite regulation

• Inflammation control
  – Neuroendocrine and neuroimmune modulation

• Motor / musculoskeletal rest
  – Intuitive
Some new facts about sleep

• Highly local process
  – Slow waves, UP/DOWN states, traveling waves

• Use-dependent features

• Complex network dynamics
  – Ocean waves

• Complex synaptic dynamics
  – Worm-like
  – Synaptic homeostasis model
How Much Sleep?

A) 6 hours  
B) 7 hours  
C) 8 hours  
D) 9 hours

“It depends, but super-humans are rare outside the movies…..”
Common disruptors of sleep

- Pain
- Anxiety/depression
- Stress
- Sleep apnea (public enemy #1 for sleep)
- Circadian misalignment
- Drugs
- Medical training!
Physiologic Determinants of Sleepiness

Normal Sleepiness

- Sleep Drive
- Wake Propensity
- Circadian Drive for Wakefulness


SLEEP ALERTNESS & FATIGUE EDUCATION IN RESIDENCY
© 2006 American Academy of Sleep Medicine
Neurobiologic Effects of Sleep Loss

Alertness and vigilance become unstable and unreliable

Cognitive slowing occurs and time pressure increases errors

Tasks may be begun well, but performance declines with increasing rapidity

There is growing neglect of activities judged to be nonessential (loss of situational awareness)

Involuntary sleep attacks begin to occur

Risks of accidents and crashes increase
Sleepiness in residents is equivalent to that found in patients with serious sleep disorders.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Epworth Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>5.90</td>
</tr>
<tr>
<td>Insomnia</td>
<td>2.20</td>
</tr>
<tr>
<td>Sleep Apnea</td>
<td>11.70</td>
</tr>
<tr>
<td>Residents</td>
<td>14.70</td>
</tr>
<tr>
<td>Narcolepsy</td>
<td>17.50</td>
</tr>
</tbody>
</table>

Papp et al, Academic Medicine, 2002
Mustafa et al, Sleep and Breathing, 2005
Resident Self-reported Errors by Average Daily Hours of Sleep

Baldwin & Daugherty, Sleep, 2004
Residents Averaging Less Than Five Hours of Sleep per Night

Were significantly more likely to report:

<table>
<thead>
<tr>
<th>Event</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involvement in a malpractice suit</td>
<td>2.02</td>
</tr>
<tr>
<td>Use of medication to stay awake</td>
<td>1.91</td>
</tr>
<tr>
<td>Serious conflict with other residents</td>
<td>1.86</td>
</tr>
<tr>
<td>Accidents/injuries</td>
<td>1.84</td>
</tr>
<tr>
<td>Making a serious medical error</td>
<td>1.74</td>
</tr>
<tr>
<td>Noticeable weight change</td>
<td>1.59</td>
</tr>
<tr>
<td>Increased use of alcohol</td>
<td>1.52</td>
</tr>
<tr>
<td>Serious conflict with nursing staff</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Baldwin & Daugherty, Sleep, 2004
Sleep Deprivation Decreases Attention

Van Dongen et al, Sleep, 2003
Cumulative adverse effects of chronic partial sleep restriction are greater in objective than subjective measures.

Neurobehavioral effects of sleep loss

Deficits

Objective

Subjective

Days of sleep restriction

Days of sleep restriction

4h TIB
6h TIB
8h TIB
Sleep Fragmentation Affects Sleep Quality

NORMAL SLEEP

ON CALL SLEEP

Morning Rounds
Subject 1 (dotted line) is more vulnerable to sleep loss than subject 2 (solid line)
Impaired Speed and Errors in Performance: Laparoscopic Surgical Simulator

Pre and post 17-hour overnight call duty in a surgical department (median reported sleep time 1.5 h; range 0-3 h)

Grantcharov TP et al, BMJ, 2001
Cognitive Performance on Awakening From Sleep Compared with Subsequent Sleep Deprivation

Wertz et al, JAMA, 2006
Intern Sleep and Patient Safety Study

• Randomized trial comparing interns’ alertness and performance on traditional “q3” schedule with 24-30 hour shifts (ACGME-compliant) vs. 16 hr max schedule

• Results: *Twice as many* EEG-documented attentional failures at night on traditional schedule

---

![Bar chart showing attentional failures at night between groups](chart.png)

Between Groups p=0.02

Intern Sleep and Patient Safety Study

Results: 36% more serious errors on traditional schedule, including five times as many serious diagnostic errors.

Harvard Work Hours, Health, and Safety Study: Motor Vehicle Crash Risk in Interns on Commute Home from Hospital

OR: 2.3, p<0.001

Driving Simulator

Condition effects:
P < 0.001
No effect of sex or training year

Arnedt et al. JAMA 2005
The Effects of Sleep Loss are Cumulative

Psychomotor vigilance task (PVT) performance during baseline (B), sleep restriction (P) and recovery (R)

Dinges et al, SLEEP, 1997
Recovery Sleep and Attention

Belenky et al, J. Sleep Research, 2003
Hmm.....

- In rats, chronic partial sleep loss shows neuronal stress signals which do not see to resolve over weeks
- Sleep deprivation/fragmentation increases amyloid/tau
- Sleep (undisturbed, good) needed for gunk clearance from brain
- Sleep deprivation damages locus ceruleus and other wake promoting structures
Sleep Inertia

• State of impaired cognition, grogginess, disorientation experienced upon waking from sleep
  – Increased if awakened from slow wave sleep
• Studies suggest severe cognitive impairments lasting up to 10 minutes after awakening*
  – Worse than performance after 26 hr sleep deprivation
  – Residual effects up to two hours

*Wertz, JAMA, 2006
Tassi and Muzet, Sleep Med Rev, 2000
Impact of sleepiness on behavior

- Emotional flattening (perceptive)
- Emotional flattening (expressive)
  - Voice analysis can detect
- Irritability
- Loss of humor perception
- Social cognitive skills including reading emotions
  - Brain imaging (e.g., fMRI) shows substantial and consistent neural network modifications following sleep deprivation
Randomized Trials

- No impact of shortened hours on risk
- Impact of shortened hours on “happiness”
- Thus, ACGME has moved back to 24 hours for Interns
- Supervision and system redundancy likely reduce impact of sleep loss
  - Nocturnists
  - On call Attending Physicians are actually called
  - Computer assistance
  - Team work (nursing, pharmacy)
  - Caffeine
Countermeasures

• Sleep is the BEST countermeasure
• Recovery sleep process not well understood
  – After 7 days PSD (3 or 5 hrs TIB), 3 nights insufficient
  – After 64 hours TSD, 2 nights mostly sufficient
  – Objective residual impairment persists for unknown durations
Countermeasures

• Naps

• Serve as effective, short-term countermeasure
  – 45 min may be minimum length during SD
  – 10 minute naps after 1 night PSD?
  – Particularly useful when taken prior to onset of SD

• Can help even when well-rested
Caffeine

- Reduces some sleep-related deficits at doses of 75-150 mg
- **Strategic** consumption is key
- Effects within 15 – 30 minutes; half-life 3 to 7 hours
- Use for temporary relief of sleepiness
- Cons:
  - Can disrupt subsequent sleep (more arousals)
  - Tolerance may develop
  - Diuretic effects

*Bonnet et al SLEEP 2005*
## Caffeine Content

<table>
<thead>
<tr>
<th>Product</th>
<th>Serving Size</th>
<th>Caffeine (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cola</td>
<td>8 oz</td>
<td>30 -- 45</td>
</tr>
<tr>
<td>Tea</td>
<td>8 oz</td>
<td>10 – 70</td>
</tr>
<tr>
<td>Orange soda</td>
<td>8 oz</td>
<td>0 – 40</td>
</tr>
<tr>
<td>Mountain Dew</td>
<td>8 oz</td>
<td>57</td>
</tr>
<tr>
<td>Red Bull</td>
<td>330 ml</td>
<td>80</td>
</tr>
<tr>
<td>Drip Coffee</td>
<td>7 oz</td>
<td>110 – 175</td>
</tr>
<tr>
<td>Starbucks Grande</td>
<td>16 oz</td>
<td>260</td>
</tr>
<tr>
<td>No-Doze</td>
<td>1 tab</td>
<td>100</td>
</tr>
<tr>
<td>Vivarin</td>
<td>1 tab</td>
<td>200</td>
</tr>
</tbody>
</table>
Countermeasures

• Bright Light
  – Effective for sleepiness and subjective measures
  – Objective measures less clear

• Exercise
  – Only very short-term benefit, but longer-term

• Posture
  – Temporarily effective, at least for attention

• “Driving” strategies
  – Completely ineffective
Dealing with shift work

• Large inter-individual differences
• Different strategies for random vs. clustered/block shift-work
• Light, sleep, activity, drug, avoid naps if likelihood of rapid action post-awakening
Residents Report Using:

**Melatonin**: minimal effect in ER resident studies

**Amphetamines/MPH***: can improve psychomotor performance and promote subjective alertness at 10-20 mg; adverse effects sleep, CV and metabolic/ neuroendocrine measures, high abuse potential

**Modafinil (Provigil)* and Armodafinil (Nuvigil)**: Variable improvement performance, alertness, mood at doses 100-400mg; may result in subjective “overconfidence,” disrupted sleep

*Bonnet et al SLEEP 2005*
Summary

• Sleep is necessary for brain and body
• Sleep loss has biological consequences
• Only sleep (maybe some forms of anesthesia) can combat sleepiness
• Sleep loss will ultimately result in “brain failure”
• Sleep loss has implications for “everyone”
• Professional duty hours are under increasing scrutiny
  – Transportation, air-traffic controllers, pilots, medical trainees
• Understanding sleepiness biology increased respect for sleep and sleepiness