**Supplemental Table 39. Overview of Normal Sleep and its Architecture as Characterized by Polysomnography**

***Normal Sleep***

Sleep is divided into two main types: rapid-eye-movement (REM) sleep and non-rapid-eye-movement (NREM) sleep. REM sleep is characterized by low amplitude, high-frequency EEG waves as well as rapid eye movements. NREM sleep can be broken down into three distinct stages: N1, N2, and N3. With progression from N1 to N2 to N3, EEG waves become slower and more synchronized, sleep becomes “deeper” with a higher threshold for arousal from sleep (more difficult to arouse from sleep) and eyes remain still. In stage N3 sleep, EEG waves are of high-amplitude and low-frequency with spindles.

During a “normal” eight hour period of sleep, healthy adults will cycle through the various sleep stages throughout the night. Typically, sleep begins with a transition from wakefulness to N1, the first and “lightest” stage of sleep, lasting 1-7minutes, and then transitions into stage N2 sleep, which generally lasts 10-25 minutes. If uninterrupted, N2 sleep gives way to N3 sleep, the deepest NREM stage of sleep, which generally lasts 20-40 minutes. Following N3 sleep, there is often a return to lighter NREM sleep stages, for example a 5-10 minute period of N2, prior to the initial REM sleep episode. The first REM period may last only 1-5 minutes.

The average length of the first complete “cycle” through all the sleep stages is typically between 70-100 minutes, with later cycles taking approximately 90-120 minutes. The majority of N3 sleep occurs in the first part of the night, with later cycles revealing shorter N3 periods or none at all; whereas REM sleep periods typically become longer through subsequent cycles. Slow wave sleep (N3) is of longest duration in young children, and decreases steadily with age such that elderly adults with “normal” sleep may have no N3 sleep at all.

***Polysomnography:***

Polysomnography includes the measurement of electroencephalography (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), pulse oximetry, respiratory effort (thoracic and abdominal), nasal airflow, and sound. Many published studies utilizing polysomnography to measure sleep in the ICU report sleep according to the R+K method (1). More recent studies utilize the newer AASM rules (2). A description of both are included in two tables below for clarity.

An irregular sleep schedule, sleeping during the day, missing a night’s sleep, frequent interruptions, medications/drugs, alcohol, exercise, stress, and environmental factors such as temperature and light can all alter normal sleep patterns, quantity and quality. Polysomnography measures not only the “architecture” of sleep (the time spent in each sleep stage, and the timing/pattern of sleep stages throughout the sleep period) but also the duration, continuity, fragmentation and latency of sleep as depicted in second table.

**References:**

1. Rechtschaffen A., Kales A. A manual of standardized terminology, techniques, and scoring systems for sleep stages of human subjects. Los Angeles: UCLA Brain Information Service/Brain Research Institute, 1968
2. Iber C, Ancoli-Israel S, Chesson AL, et al. The AASM Manual for the Scoring of Sleep and Associated Events. American Academy of Sleep Medicine; West Chester, IL: 2007

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| **AASM** **(2007)** | **R & K (1968)** | **Description** | **Polysomnography Criteria** | **Normal Values in Healthy Adults** |
| Stage W (Wakefulness) | Waking | “Awake” | * >50% of the epoch\* consists of alpha (8-13 Hz) activity or low voltage, mixed (2-7 Hz) frequency activity
 |  |
| Stage N1 (NREM 1 sleep) | Stage 1 | “Light Sleep” * transition between wakefulness and sleep;
* may still feel aware of surroundings;
* may easily be aroused back to wakefulness
 | * 50% of the epoch consists of relatively low voltage mixed (2-7 Hz) activity, and <50% of the epoch contains alpha activity.
* Slow rolling eye movements lasting several seconds often seen in early stage 1
 | * 3-8%

of TST |
| Stage N2 (NREM 2 sleep) | Stage 2 | * breathing and heart rate begin to slow;
* arousal threshold slightly higher
 | * Appearance of sleep spindles and/or K complexes and <20% of the epoch may contain high voltage (>75 μV, <2 Hz) activity.
* Sleep spindles and K complexes each must last >0.5 seconds
 | * 45-55% of TST
 |
| Stage N3 (NREM 3 sleep) | Stage 3  | “Deep Sleep”“Slow Wave Sleep” * referred to as delta sleep or slow wave sleep;
* thought to be a regenerative period for the body to heal and repair itself;
* N3 sleep decreases with age such that elderly people may have no measured N3 sleep at night
 | * 20%-50% of the epoch consists of high voltage (>75 μV), low frequency (<2 Hz) activity.
 | * 13-23% of TST
 |
| Stage 4  | * >50% of the epoch consists of high voltage (>75 μV) <2 Hz delta activity
 |
| Stage R (REM sleep) | Stage REM  | “Rapid Eye Movement Sleep”* heart rate and breathing increase and become irregular;
* vivid dreams during REM sleep;
* brain is extremely active and eyes move back and forth;
* skeletal muscles temporarily paralyzed
 | * Relatively low voltage mixed (2-7 Hz) frequency EEG with episodic rapid eye movements and absent or reduced chin EMG activity
 | * 20-25% of TST
 |

AASM = American Academy of Sleep Medicine, R&K = Rechtschaffen and Kales, EEG = electroencephalophraphy, EMG = electromyography, REM = Non-Rapid Eye Movement, REM = Rapid Eye Movement, TST = Total Sleep Time

\*epoch = 30 seconds

Overview of Polysomnography Measurements and Normal Values in Healthy Adults

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| --- | --- | --- |
| **Polysomnography Measure** | **Description (AASM 2007)** | **Normal Values in Healthy Adults** |
| ***Quantity / Duration:*** |
| Total sleep time (TST) | # minutes spent sleeping |  |
| Total recording time (TRT) | # minutes of PSG recording from “lights off” to “lights on” |  |
| Sleep efficiency (SE) | % time spent sleeping / time in bed (from “lights off” to “lights on”)=TST/TRT x100 | 80% |
| Sleep Period time (SPT) | time of initial sleep onset to time of final wakening |  |
| ***Latency:*** |
| Sleep onset latency (SL) | # minutes elapsing from “lights out” to onset of sleep  | <30 min |
| REM latency | # minutes elapsing from onset of sleep to onset of first REM period | 60-120 min |
| ***Fragmentation*** |
| Arousal | an abrupt shift of EEG frequency (including alpha, theta or frequencies >16 Hz but not spindles) lasting at least 3 seconds with 10 seconds of preceding stable sleep |  |
| Awakening | an abrupt shift of EEG frequency to wakefulness lasting at least 30 seconds (R&K definition) |  |
| Arousal Index | # arousals/hour of TST=# arousals x60/TST | 10-12/hr age 2020-22/hr age 50 |
| Sleep Fragmentation Index | # (arousals + awakenings)/ hour of TST |  |
| ***Continuity:*** |
| Sleep maintenance efficiency (SME) | % of sleep period spent sleeping=TST/SPT x100 |  |
| Sleep period time ratio | total sleep time divided by the number of sleep periods=TST/# SP, where Sleep period is defined as any period of sleep >30 seconds  |  |
| Stage Shifts | # of shifts between sleep stages |  |
| Stage N1 shifts | # shifts into stage N1 from other sleep stages |  |
| ***Architecture / Sleep Stage Summary*** |
| Wake after sleep onset (WASO) | # minutes spent in Stage W after initial sleep onset=TRT –SL – TST in minutes |  |
| Stage N1 | # minutes spent in Stage N1 OR% N1 = N1 (min)/TST x100 | 3-8% of TST |
| Stage N2 | # minutes spent in Stage N2 OR% N2 = N2 (min)/TST x100 | 45-55% of TST |
| Stage N3 | # minutes spent in Stage N3 OR% N3 = N3 (min)/TST x100 | 13-23% of TST |
| Stage REM | # minutes spent in Stage REM OR% REM = REM (min)/TST x100 | 20-25% of TST |