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# Assessment and Monitoring of Sleep in the Intensive Care Unit

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**Keywords**

critical care; sleep; sleep quality; polysomnography; actigraphy; bispectral index; sleep assessment; sleep questionnaire

## Introduction

Sleep disturbances have been identified as one of the most distressing symptoms experienced during hospitalization in an intensive care unit (ICU).[1,2] Sleep in the ICU is severely fragmented, with increased arousals and awakenings, and with almost half of total sleep time spent during daytime hours. ICU patients experience prolonged time spent in the "light sleep" stage (stage N1), with very little time spent in "deep sleep" stages (stages N2 and N3) and rapid eye movement (REM) sleep.[3] Comparisons of normal sleep in healthy adults, versus sleep experienced by ICU patients, are summarized in Table 1.

A multitude of factors can contribute to sleep disturbances in the ICU, including patient characteristics (e.g., age, severity of illness), environmental factors (e.g., light, noise), and treatment (e.g., mechanical ventilation, sedation, medications). Sleep deficiency has implications on both physiological recovery and psychological sequelae throughout critical illness. Consequently, clinicians and researchers have developed and implemented non-pharmacological sleep promotion protocols[4] to improve sleep in the ICU; however, evaluating the efficacy of these interventions is limited by the challenges of measuring and monitoring sleep in ICU patients.

Thus, the purpose of this review is to discuss and critique methods of assessment and monitoring of sleep in the ICU.

### Polysomnography

Physiologic sleep monitoring with polysomnography is the gold standard of sleep measurement in both adult and pediatric patients. Standard polysomnography includes electroencephalography (EEG), electrooculography (EOG), electromyogram (EMG),

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electrocardiogram (ECG), and recordings of airflow, respiratory effort, oxygen saturation, and limb EMG. EEG records the brain's surface electrical activity, EOG records changes that occur with eye movements, EMG records periodic limb movements, and ECG records heart rate.[5] Standard polysomnography requires the continuous presence of a sleep-trained technician who carefully applies up to 20 electrodes/sensors and monitors the patient.

Using polysomnography, sleep can be scored into non-rapid eye movement (NREM) sleep or rapid eye movement (REM) sleep.[5] NREM stage N1 sleep is characterized by low-amplitude, mixed-frequency EEG activity of predominantly 4–7 Hz activity. NREM stage N2 sleep is characterized by the presence of 1 or more K complexes without associated arousals, or 1 or more trains of sleep spindles, with total duration of 0.5 seconds or greater. A K complex is a well-delineated biphasic wave, and a sleep spindle is a train of sinusoidal waves with frequencies between 11–16 Hz. NREM stage N3, which represents slow wave sleep, is characterized by waves of frequencies between 0.5–2 Hz, and peak-to-peak amplitudes greater than 75 microvolts. REM sleep is characterized by low amplitude mixed-frequency EEG activity without K complexes or sleep spindles, low chin EMG tone, and rapid eye movements.[5] Scoring and interpretation of standard polysomnography requires extensive technical expertise and certification.

A majority of polysomnographic studies in the ICU have been conducted in non-sedated ICU patients and also tend to have very small sample sizes.[6] The inter-rater reliability (kappa) of polysomnography in ICU patients is about 0.83.[7,8] The reliability of polysomnography in the ICU is further reduced by the critical care environment. For example, it can be difficult to remove electrical artifact caused by various equipment used on ICU patients. In addition, polysomnographic monitoring of sleep in the ICU may negatively impact patient care activities, such as frequent repositioning to prevent skin breakdown.

A number of disadvantages of polysomnography have likely contributed to the small number of critical care studies. As mentioned, a certified sleep technician is required for lengthy setup, throughout monitoring, and for scoring. There may also be subjectivity when scoring some stages of sleep, especially NREM stage N1 sleep. The numerous electrodes involved in standard polysomnography may affect sleep in non-sedated patients, who may feel constrained by the presence of these leads. Dislodgment can occur as well. Finally, the cost of polysomnography is significantly high.

## Bispectral Index

The bispectral index (BIS) integrates data from multiple analyses of raw electroencephalography (EEG) waveforms: power spectral analysis, bispectral analysis, and time-based analysis for suppression/non-suppression.[9] A patient with a score between 90–100 is considered awake. A BIS score of 75–90 is considered light sleep, a score of 20–70 is considered slow-wave sleep, and REM sleep can occur at BIS scores between 75–92.[10] A score of 0 indicates a flatline EEG. Measurement of sleep with the BIS does not require the continuous presence of a trained sleep technician. Instead, BIS can be utilized by non-specialists. In comparison to polysomnography, the BIS sensors are easily applied and re-applied on the patient, and a screen can provide a preliminary view of sleep quantity. Similar to polysomnography, however, BIS is subject to electrical interference. Some patients may find the sensors intrusive and can easily remove them. The BIS is not recommended for routine monitoring of sleep in the ICU.

There are some limitations to the use of BIS in critical care settings. BIS is an indicator of sedation depth, not sleep stage.[11] When compared to polysomnography, the BIS is unable to accurately distinguish sleep stages. In anesthesia, the use of BIS has been recommended to guide dosage of anesthetics to avoid too light or too deep sedation: the recommended BIS score range is between 40–60 during anesthesia, and about 55–70 at 15 minutes prior to the end of surgery.[12] Moreover, BIS scores correlate with neurological status in non-sedated ICU patients.[13] That is, higher BIS scores correlate with better neurological function, indicating that ICU patients with neurological disorders, such as stroke or traumatic brain injury, would have lower BIS values that may not provide an accurate measurement of sleep. ICU delirium, which can occur in up to 80% of mechanically ventilated ICU patients,[14] could also affect BIS scores.

## Actigraphy

In recent years, the increased availability of actigraphy has led to its more frequent use as a surrogate measure of sleep instead of polysomnography. Wrist actigraphy, a measure of wrist movements (gross motor activity) to assess sleep or wake state, utilizes accelerometry within a small, lightweight, wrist-worn device that often looks like a watch. Actigraphs can collect data over extended time periods, which can then be downloaded onto a computer. Its software is based on validated scoring algorithms that translate accelerometry data into sleep/wake periods. Validation of actigraphy compared to polysomnography among a variety of participants under controlled sleep laboratory conditions has demonstrated high sensitivity (0.965) and accuracy (0.863) with low specificity (0.329).[15] Actigraphy has also been validated for sleep assessment in healthy infants and children.[16,17]

Actigraphy has not undergone rigorous validation against polysomnography in the ICU setting. Actigraphy tends to overestimate sleep in ICU patients due to inactivity and immobility, especially in sedated and mechanically ventilated patients. Agreement between actigraphy versus polysomnography in the ICU could range as low as 65%.[18] Actigraphy-based studies measuring sleep in the ICU often report wide ranges of sleep quantity. For example, using actigraphy, the mean nighttime total sleep time may range from 4.4–7.8 hours, the mean time spent awake after sleep onset may range from 12–204 minutes, and the mean sleep efficiency (total sleep time divided by total time spent in bed) may range from 61–75%.[19] Actigraphy demonstrates fewer mean nighttime awakenings compared to polysomnography, but higher mean nighttime awakenings compared to nursing assessment or patient-reported sleep.[19] Actigraphic movements have also been correlated with non-sleep critical care outcomes, such as agitation and sedation[20] and postoperative delirium.[21]

Advantages of actigraphy over polysomnography or BIS include its low-cost, noninvasive sensor technology, which does not require the presence of a sleep technician, and can collect data for days or even weeks. Because wrist actigraphs are small, they are not bothersome and are unlikely to be removed by the patient. It is often used for evaluation of sleep-related outcomes in intervention studies, and some actigraphs can simultaneously measure ambient light in the ICU environment. Actigraphy is also feasible for continuous monitoring in pediatric ICU patients.[22] However, as previously mentioned, actigraphic data should be interpreted cautiously in ICU patients. Neuromuscular weakness, such as that observed in ICU-acquired weakness or neurological injury, increases the risk of overestimating total sleep time and sleep efficiency. As ICU patients are often sedated or mechanically ventilated, prolonged periods of inactivity may be inaccurately scored as sleep. Another disadvantage in the use of actigraphy is the risk of removal by nursing staff, who may remove the actigraph during bathing or related care activities, and may forget to replace the device afterwards. Although routine use of actigraphy for physiologic sleep monitoring is not recommended in the ICU, its relative ease of use and lower cost compared to polysomnography and BIS make it a popular surrogate measure of sleep.[19]

## Nursing Assessment

Although physiologic sleep monitoring is not recommended for routine sleep assessment in the ICU, nurses should attempt to monitor sleep by using validated sleep assessments. Inquiring about patients' sleep may serve as a necessary first step to addressing patients' and families' concerns about sleep as a distressing symptom.

Edwards and Schuring's Sleep Observation Tool (SOT)[23] was developed in the ICU setting as a method of observing patients' sleep at 15-minute intervals. The SOT asks nurses to assess patients every 15 minutes as asleep, awake, could not tell, or no time to observe. When compared with polysomnography, nurses using the SOT correctly identified sleep 81.9% of the time.[23] While the SOT is the most valid questionnaire for nurse-observed sleep quality, it is not practical for routine use due to its frequent intervals. For example, Dennis and colleagues asked nurses to observe patients using the SOT seven times a day, instead of at 15-minute intervals.[24]

Another sleep measure utilizing nursing observation is the Echols Patient Sleep Behavior Observation Tool (PSBOT), which has demonstrated moderate convergent validity for wake after sleep onset and sleep latency.[25] The PSBOT describes four levels of vigilance: awake, drowsy, paradoxical (REM) and orthodox (non-REM) sleep. The PSBOT has also been used in pediatric ICU studies.[26,27]

Other nursing assessments have been reported in the literature; however, their reliability has not been reported. Beecroft et al.'s questionnaire[18] included only two simple items: 1. "How many hours did your patient sleep during the study period?" and 2. "How many times did your patient wake during the study period?" Nurses answer these two questions about their patient with regards to the previous night. Beecroft and colleagues did not find a significant correlation between nurse-observed sleep and polysomnography.[18] Ibrahim et al.'s assessment[28] was designed for ICU nurses to visually observe patients and document their findings, such as: eyes closed, decreased motor activity, lack of interaction with the environment, and lack of purposeful activity. Yet Ibrahim and colleagues also did not report criterion validity or reliability compared to polysomnography.

Nursing assessment of sleep does carry significant limitations. Seminal studies of nurse-observed sleep[18,23,25,29] revealed that nursing observation tends to overestimate total sleep time in comparison to sleep evaluation with polysomnography. Nursing observation of patients' sleep could be useful, given that observation does not require participation from the patient. However, ICU patients who are unable to move or frequently close their eyes while remaining awake could be mistakenly judged as asleep.

### Patient Questionnaires

Patient-oriented sleep questionnaires may be a more assistive tool than nursing observation in measuring patients' perceptions of sleep quality. Herein, several sleep questionnaires are described in greater detail.

The Richard-Campbell Sleep Questionnaire (RCSQ)[7] has demonstrated validity and reliability in adult ICU patients to evaluate patients' perceptions of their own sleep, given that the patient is both alert and oriented. The RCSQ is a brief, 2-minute questionnaire designed to assess sleep perceptions in the ICU. It consists of five visual analog scales, with each scale representing a different sleep domain. Scores on each domain can range from 0 to 100, indicating poor to excellent sleep quality, with higher scores indicating better sleep quality. Patients are instructed to place or indicate an "X" along each visual analog scale to rate the quality of the respective sleep domain from the previous night. The RCSQ total score is regarded as a global measure of sleep quality. Although the RCSQ is considered the best available option for measuring ICU patients' perceptions of sleep quality,[6,30] the RCSQ can only be obtained from ICU patients who are cognitively able to participate.

The Verran and Snyder-Halpern Sleep Scale,[31] originally developed and tested in healthy participants, has also been tested in ICU patients,[7,25] with limited convergent validity ($r = 0.39$).[25] One study reported that there was no statistically significant difference between the Verran and Snyder-Halpern Sleep Scale and actigraphy-observed total sleep time among acute care patients.[32]

The Sleep in the ICU Questionnaire has been developed to address ICU sleep quality with seven domains and 27 questions, where patients provide ratings on a 1–10 scale. However, the reliability of this questionnaire has not been compared to polysomnography. The Pittsburgh Sleep Quality Index (PSQI)[33] is a widely used and reliable sleep questionnaire, yet it was developed in a psychiatric population to assess sleep quality over a 1-month period, and thus is not sensitive to daily variability in sleep.

While patient-reported subjective sleep measures can provide valuable insight to patients' perceptions of sleep, there are significant differences in results obtained from self-report versus objective measures.[34] Subjective sleep measures should not entirely replace objective sleep measures, but these two could be used to complement each other to measure sleep in the ICU.

## Discussion

The ICU environment poses unique challenges for sleep assessment and monitoring. All of the aforementioned methods have their own respective limitations. How to best measure sleep in the ICU setting is still debated; routine monitoring of any neurological activity remains challenging in the ICU environment. A summary of the advantages and disadvantages of instruments for sleep assessment in the ICU are presented in Table 2.

The latest clinical practice guidelines for the management of sleep disruption in the ICU[35] conditionally states that physiologic sleep monitoring using polysomnography, electroencephalography, bispectral analysis, or actigraphy is not recommended for ICU patients. The rationale behind this recommendation is due to a lack of high-quality evidence from studies investigating clinically important outcomes: physiologic monitoring has not yet been adequately studied with respect to outcomes of delirium, duration of mechanical ventilation, ICU length of stay, or ICU mortality.[35] Moreover, there is a high cost associated with implementation of these measures.

Although routine physiologic sleep monitoring is not recommended in the ICU, the clinical practice guidelines do emphasize that nurses should routinely assess patients' sleep by either a validated assessment tool (i.e., the RCSQ) or by an informal nursing assessment and/or electronic medical record-based documentation.

Future studies of sleep measures should include factors that influence sleep in addition to sleep itself. Studies have identified environmental (e.g., noise, light), pathophysiologic (e.g., pain, difficulty breathing, coughing, hunger/thirst), care-related (e.g., vital signs, procedures, diagnostic tests, medication administration, catheters), and psychological (e.g., anxiety, disorientation, lack of privacy) factors that patients report as disruptive to sleep.[35,36] Assessment of these factors, in combination with a sleep questionnaire, may provide valuable data on sleep.

## Summary

Studies of sleep in ICU patients have consistently reported poor sleep quality. Sleep deficiency may increase the risk of ICU-related complications, such as delirium, ICU length of stay, and mortality.[37] Routine physiologic monitoring of sleep using polysomnography, BIS, or actigraphy is not recommended. Instead, sleep should be routinely assessed by patient questionnaire or informal nursing assessment. Future development of sleep measures, including patient questionnaires, should feature ICU-related factors that influence sleep to best monitor sleep in the ICU.

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**Key Points:**

- Sleep disturbances are one of the most distressing symptoms experienced during critical illness hospitalization.
- The ICU environment poses unique challenges for sleep assessment and monitoring.
- Methods of assessment and monitoring of sleep in the ICU include polysomnography, bispectral index, actigraphy, nursing assessment, and patient questionnaires.

**Synopsis:**

Sleep affects physiological and psychological recovery throughout critical illness. Patients often describe poor sleep as a major source of distress while hospitalized in an intensive care unit (ICU). The purpose of this literature review is to discuss methods of assessment and monitoring of sleep within the ICU setting. The advantages and disadvantages of physiologic monitoring of sleep (e.g., polysomnography, bispectral index, and actigraphy) are compared with those of subjective measures of sleep quality (e.g., validated patient-oriented sleep questionnaires, and informal nursing assessments).

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**Clinics Care Points:**

- When assessing sleep in ICU patients, routine physiologic monitoring using polysomnography, electroencephalography, bispectral index, or actigraphy is not recommended for ICU patients.
- Validated patient-oriented sleep questionnaires and/or informal nursing assessments are recommended for routine assessment of sleep in ICU patients.

**Table 1:**
**Comparison of Normal Sleep versus Sleep in the Intensive Care Unit**

Normative sleep data of healthy adults are summarized here, based on a systematic review and meta-analysis of polysomnography data.[38] Sleep data of ICU patients are summarized here, based on a systematic review of actigraphy data (total sleep time, sleep efficiency, and wake after sleep onset)[19] and from seminal polysomnography studies in ICU patients (NREM stages N1, N2, N3, and REM).[39–42]

| Sleep Parameter | Normal Sleep: Healthy Adults[38] | Sleep: ICU Patients[19,39–42] |
|---|---|---|
| **Total Sleep Time** | Ages 18–34: 6.84 hours<br>Ages 35–59: 6.44 hours<br>Ages 50–64: 6.2 hours<br>Ages 65–79: 5.77 hours<br>Ages ≥ 80: 3.31 hours<br>Mean: 6.6 hours | Range, nighttime: 4.4–7.8 hours<br>Range, 24-hour cycle: 7.1–12.1 hours |
| **Sleep Efficiency** | Ages 18–34: 89%<br>Ages 35–59: 85.4%<br>Ages 50–64: 83.2%<br>Ages 65–79: 77.5%<br>Ages ≥ 80: 45.7%<br>Mean: 85.7% | Range: 61–75% |
| **Wake After Sleep Onset** | Ages 18–34: 32.1 minutes<br>Ages 35–59: 51.1 minutes<br>Ages 50–64: 64 minutes<br>Ages 65–79: 77.1 minutes<br>Ages ≥ 80: Not available<br>Mean: 48.2 minutes | Range: 12–204 minutes |
| **NREM Stage N1** | Ages 18–34: 6%<br>Ages 35–59: 8%<br>Ages 50–64: 8.7%<br>Ages 65–79: 9.3%<br>Ages ≥ 80: 27.5%<br>Mean: 7.9% | Accounts for more than half of total sleep time |
| **NREM Stage N2** | Ages 18–34: 51.3%<br>Ages 35–59: 52.2%<br>Ages 50–64: 52.8%<br>Ages 65–79: 53.3 %<br>Ages ≥ 80: 43.5%<br>Mean: 51.4% | Slightly decreased or normal |
| **NREM Stage N3** | Ages 18–34: 21.4%<br>Ages 35–59: 20.4%<br>Ages 50–64: 18.1%<br>Ages 65–79: 19.9%<br>Ages ≥ 80: 19.1%<br>Mean: 20.4% | Marked decrease in slow wave sleep |
| **REM Stage** | Ages 18–34: 19.8%<br>Ages 35–59: 19.3%<br>Ages 50–64: 18.7%<br>Ages 65–79: 17.7%<br>Ages ≥ 80: 9.9%<br>Mean: 19% | Marked decrease or almost absent |

Table Abbreviations/Definitions:

Total sleep time: total time spent in sleep stages.

Sleep efficiency: total sleep time divided by total time spend in bed. Wake after sleep onset: time spent awake after onset of sleep.

NREM: non-rapid eye movement sleep.

REM: rapid eye movement sleep.

**Table 2:**

Methods for Sleep Assessment in the Intensive Care Unit

| Instrument | Advantages | Disadvantages | Clinical Application |
|---|---|---|---|
| **Polysomnography (PSG)** | Gold standard of sleep measurement<br>Standard diagnostic test for obstructive sleep apnea<br>Can monitor sleep stages<br>Can monitor sleep quality<br>Age-adjusted normative sleep data is available for comparison | Presence of sleep technician required throughout monitoring<br>Sleep technician required to score results<br>Time needed for scoring<br>Lengthy setup time required<br>Requires technician to adjust electrodes if removed<br>Physiological conditions or injuries (e.g., burns) could limit lead placement<br>Interpretation of sleep architecture in sedated patients can be difficult | Physiologic monitoring of sleep not routinely recommended |
| **Bispectral Index (BIS)** | Continuous monitoring<br>No technician required throughout monitoring<br>No technician required to adjust or replace sensors<br>Screen may give a quick view of sleep | Patient or staff removal of sensors<br>Cannot reliably evaluate sleep stages<br>Can be affected by neurological state (e.g., delirium) | Physiologic monitoring of sleep not routinely recommended |
| **Actigraphy** | Continuous monitoring over days to weeks<br>No technician required throughout monitoring<br>No technician required to reapply<br>Lower cost than PSG and BIS<br>Unlikely to be removed by patient<br>May be able to simultaneously measure light | Nursing staff removal of watch Cannot evaluate sleep stages Periods of inactivity may be incorrectly scored as sleep | Physiologic monitoring of sleep not routinely recommended |
| **Nursing Assessments** | Easy to implement in routine ICU care | Overestimates total sleep time Frequent assessments are required for optimal measurement<br>Potential risk of missing data due to other patient care activities<br>Nurses may not document accurately | Routine monitoring of sleep using patient-oriented question naires is recommended Results should be interpreted cautiously |
| **Patient Questionnaires** | Quick to complete<br>Patients can compare baseline sleep quality to current sleep quality | Patients may lack time cues for day and night in the ICU setting<br>Patients must be alert and oriented (i.e., cannot be used in patients with acute or chronic cognitive dysfunction) | Routine monitoring of sleep using patient-oriented questionnaires is recommended<br>Cannot be used in patients with cognitive impairment, delirium, or dementia |