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REVIEW

# Assessment of sleep quality in the Intensive Care Unit: A comprehensive review of tools and techniques

Suchanun Lao-amornphunkul[1] , Nattaya Raykateeraroj[2] , Nuanprae Kitisin[2]

[1]Department of Intensive Care, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand, 10700;
[2]Department of Anesthesiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand, 10700

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**Corresponding author:**
Nuanprae Kitisin
Department of Anesthesiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand, 10700
Tel: (+66) 89-676-7706
E-mail: nuanprae.kit@mahidol.edu

## ABSTRACT:

Sleep disturbances are common among critically ill patients, significantly impacting recovery and overall health outcomes. Sleep in the Intensive Care Unit (ICU) is often fragmented, with reduced deeper sleep stages and disrupted circadian rhythms. This review explores a range of tools for assessing sleep quality in ICU settings, including both objective and subjective methods. Objective tools, such as polysomnography (PSG), Bispectral Index (BIS), and actigraphy, provide quantifiable data on sleep patterns but vary in their practicality and accuracy. PSG is considered the gold standard due to its comprehensive measurement of sleep stages; however, its use is limited in ICU settings due to high costs, complexity, and the need for trained personnel. BIS and actigraphy offer more feasible alternatives, but their validity and accuracy compared to PSG can vary. Subjective approaches, like patient questionnaires and nurse observation tools, offer valuable insights into perceived sleep quality but may be influenced by patient condition and cognitive status. This review evaluates the advantages, limitations, validity, and reliability of these tools, emphasizing their potential roles in clinical practice. The findings suggest the need for more tailored approaches to sleep assessment in ICU patients, acknowledging that no single tool is without limitations. Further research is needed to develop novel, reliable, and cost-effective sleep assessment methods specifically suited for the ICU, which could improve patient outcomes through better-targeted interventions for sleep disturbances.

**Keywords:** Sleep; Sleep assessment; Sleep quality; Polysomnography; Electroencephalography; Intensive Care Unit

## INTRODUCTION

Sleep is a vital physiological process, essential for maintaining health and overall well-being. In critically ill patients, sleep is frequently disrupted [1,2], and may be linked to delirium, cognitive dysfunction, psychiatric disturbances, and reduced quality of life [3]. Sleep in Intensive Care Unit (ICU) is frequently fragmented, with reduced deep, restorative phases, particularly rapid eye movement sleep [1]. In the ICU, 59% of patients described their sleep quality as poor or very poor, compared to 24% when at home [4]. The impact of sleep deprivation in the ICU extends beyond discomfort, contributing to significant physiological consequences, including increased inflammatory cytokine levels [5], impaired immune responses, and respiratory complications due to muscle fatigue [2]. Sleep disturbances are also linked to cognitive impairments, including difficulties with memory consolidation, which can further hinder recovery [3].

Numerous factors contribute to sleep disturbances in the ICU, including environmental factors such as continuous light exposure and noise, therapy-related factors such as the use of sedatives and mechanical ventilation, and patients' clinical conditions, including pain, stress, and pre-existing health conditions [6,7]. The circadian rhythm, which regulates sleep-wake cycles, is particularly vulnerable in the ICU setting. Exposure to constant artificial light, particularly blue light, interferes with melatonin production, exacerbating sleep disruptions [8].

Various tools and methodologies have been developed to assess and address sleep disturbances. While polysomnography (PSG) remains the gold standard for measuring sleep quality [9], its complexity and invasive nature make it impractical for routine use in the ICU. As a result, simpler tools like actigraphy and the Richards-Campbell Sleep Questionnaire (RCSQ) [10] are more commonly used. These methods offer practical and cost-effective ways to assess sleep quantity and quality, providing valuable insights into ICU patients' sleep experiences and the factors contributing to sleep disruptions.

This review aims to provide a comprehensive overview of the tools used to assess sleep quality in critically ill patients, examining their advantages, limitations, and validity, while highlighting their practical use in improving our understanding of sleep disturbances in ICU.

### KEY MESSAGES:

- Sleep disturbances are highly prevalent among critically ill patients and may be associated with delirium, cognitive dysfunction, psychiatric disorders, and a reduced quality of life.
- PSG is the gold standard tool for assessing sleep stages, but its application in ICU settings is limited due to practicality and resource constraints.
- Objective methods like actigraphy and bispectral index, along with subjective tools such as nurse or patient assessments, are commonly used but have limitations in validity and accuracy compared to PSG.
- Developing reliable and practical methods for assessing and enhancing sleep in the ICU is essential to improve patient outcomes and recovery.

## OVERVIEW OF SLEEP PHYSIOLOGY

**Normal sleep cycle**

Under normal physiology, sleep cycles between two primary stages-non–rapid eye movement (NREM) and rapid eye movement (REM)-approximately every 90 minutes, distinguished by specific electroencephalography (EEG) and electrooculography (EOG) patterns [11]. Sleep stages were first classified in 1968 by the Rechtschaffen and Kales (R&K) guidelines [12]. In 2007, the American Academy of Sleep Medicine (AASM) revised this classification, consolidating sleep into five stages: W (wake), N1 (formerly S1), N2 (formerly S2), N3 (combining S3 and S4), and R (REM) [13-15]. The AASM scoring manual has since undergone several updates, with the latest version published in 2023 [16], incorporating refinements to scoring criteria and technical specifications to improve the accuracy and consistency of sleep assessments.

- **Non-REM (Non-Rapid Eye Movement) sleep** is divided into three distinct stages:
  - o N1: This is the lightest stage of sleep and accounts for approximately 8% of total sleep in healthy adults aged 35 to 59. During N1, muscle tone begins to relax, and the transition from wakefulness to sleep occurs.
  - o N2: A deeper stage of sleep, N2 comprises about 52.5% of total sleep. This stage is characterized by the appearance of sleep spindles and K-complexes on EEG, which are linked with memory consolidation and decreased sensory awareness.
  - o N3: slow-wave sleep (SWS) or deep sleep accounts for approximately 20.4% of total sleep. This is the most restorative stage, characterized by EEG delta waves. N3 is crucial for physical recovery, immune function, and the release of growth hormone.
- **REM (Rapid Eye Movement) sleep:**
  - o REM sleep typically constitutes around 19.3% of total sleep in healthy adults. It is the stage most associated with vivid dreams and is critical for cognitive functions such as learning, memory consolidation, and emotional regulation. REM sleep is defined by rapid eye movements, reduced muscle tone (atonia), and brainwave activity that closely resembles wakefulness.

In a typical sleep cycle, adults progress through the stages of Non-REM and REM sleep in a predictable pattern, with the proportion of REM sleep increasing during the later stages of the night. Age, lifestyle, and health status can influence the distribution of these sleep stages. For instance, Non-REM sleep, particularly N3, typically declines with age, while REM sleep may also be altered in various sleep disorders [11].

## SLEEP PATTERNS IN ICU PATIENTS

PSG studies show substantial sleep disturbances in critically ill patients, including pronounced fragmentation, reduced efficiency, increased light sleep (N1 and N2), and reduced REM and slow-wave (N3) sleep. Total sleep time (TST) varies, sometimes preserved but shifted to daytime [17].

"Atypical sleep" and "pathologic wakefulness" describe abnormal patterns in ICU patients. Atypical sleep is characterized by the absence of sleep spindles and K-complexes, making stage 2 indistinguishable from other NREM stages. Pathologic wakefulness shows slow-wave (theta

and delta) activity even during wakefulness, complicating the differentiation from NREM sleep and potentially overestimating TST [6,18]. These results are summarized in Table 1.

## SLEEP DISRUPTION IN ICU PATIENTS

Sleep disturbances in ICU patients result from a combination of environmental, medical, and psychological factors. Environmental disturbances such as excessive noise from alarms, staff conversations, and equipment, along with constant exposure to artificial light, contribute significantly to sleep fragmentation [3]. Frequent patient care activities, including vital sign monitoring, medication administration, and repositioning, further disrupt sleep by causing multiple awakenings throughout the night [19]. Mechanical ventilation is another key contributor to sleep disruption, leading to fragmented sleep patterns, reduced sleep efficiency, and increased daytime sleep due to ventilatory effort, gas exchange abnormalities, and patient-ventilator dyssynchrony [20].

Medical and psychological factors also play a role in sleep disturbances among ICU patients. Medications commonly used in critical care, such as sedatives, opioids, and corticosteroids, can suppress deep sleep (N3) and REM sleep [21], contributing to poor sleep quality and an increased risk of delirium. Additionally, pre-existing conditions like obstructive sleep apnea (OSA), chronic respiratory diseases, and heart failure can exacerbate sleep disturbances by causing frequent arousals and nocturnal hypoxia [22]. Psychological stress, pain, and anxiety related to the ICU environment further impair sleep, making it difficult for patients to achieve restorative rest [23]. Addressing these challenges requires a comprehensive approach that minimizes disruptions and optimizes the ICU environment to promote better sleep quality and patient recovery.

## SLEEP ASSESSMENT IN ICU

Sleep is a multidimensional process involving various aspects such as sleep stages, frequency of arousals, total sleep time, sleep movement, tiredness upon awakening, and subjective perception of sleep quality.

Sleep assessment methods in the ICU can be broadly categorized into objective, subjective, and non-traditional approaches [24]. Objective measurements quantitatively evaluate sleep by monitoring physiological parameters and include tools such as PSG, bispectral index (BIS), and actigraphy. Subjective measurements rely on patient-reported or observer-based evaluations, offering insights into perceived sleep quality through patient questionnaires and nurse observation tools. Non-traditional methods are innovative approaches still under exploration for their potential application in sleep assessment within the ICU [25].

The methods for sleep assessment in the ICU are summarized in Table 2, while the comparison of sleep assessment tools for ICU patients based on key sleep quality domains is presented in Table 3.

**Table 1.** Sleep pattern in critically ill patients.

| Sleep pattern | Finding |
|---|---|
| Circadian rhythm | Markedly abnormal<br>Temporal disorganization in melatonin secretion |
| Nocturnal total sleep time | Often preserved but also drastically decreased or increased |
| Diurnal total sleep time | Increased (up to 41% of total sleep time) |
| Sleep latency | Unchanged/increased |
| Sleep efficiency | Decreased |
| NREM sleep | Increased stage 1 and stage 2<br>Markedly decreased or absent stage 3 or slow wave sleep (0–9 % of total sleep time)<br>Absence of K complexes and sleep spindles (20–44%) |
| REM sleep | Markedly decreased or absent |
| Sleep fragmentation | Increased |
| Pathologic wakefulness | Prevalence of slow wave (theta and delta) activity and the absence of normal EEG response to eye-opening |
| Atypical sleep | Absence of K complexes and sleep spindles that traditionally differentiate Stage 2 from other<br>stages of NREM sleep |

REM: rapid eye movement; NREM: non-rapid eye movement; EEG: electroencephalography

**Table 2.** Summary of methods for sleep assessment in the intensive care unit.

| Instrument | Outcome measure | Advantages | Disadvantages | Validation with PSG |
|---|---|---|---|---|
| Standard PSG | • 4–6 EEG channels, EMG, EOG, EKG, respiratory airflow and respiratory effort channel, and pulse oximetry<br>• Monitors sleep quantity and quality | • Gold standard for measuring sleep<br>• Providing comprehensive sleep data | • High cost, complexity, need for trained sleep technician<br>• Intrusive device<br>• Prone to dislodgement and electrical interference<br>• Rater subjectivity and difficult to interpretation<br>• Standard sleep interpretation criteria (the AASM criteria) may be less effective in ICU patients | • Spectral analysis of EEG significantly improved reliability [26]. |
| Multichannel EEG | • Several frontal electrode EEG | • Better portability and tolerability compared to standard PSG<br>• Providing more comprehensive sleep data than single channel EEG | • Not as effective as standard PSG for sleep staging<br>• Interpretation in critically ill patients challenging due to factors | • Strong agreement between multichannel EEG with automated sleep staging and human-scored PSG [27].<br>• Further validation is needed in critically ill populations. |
| Single channel EEG | • Frontal electrode EEG | • Better portability and tolerability compared to standard PSG<br>• Less accurate sleep data than multichannel EEG | • Not as effective as standard PSG for sleep staging<br>• Interpretation in critically ill patients challenging due to factors | • Single-channel EEG with spectral analysis showed 0.68 sensitivity and 0.59 specificity for detecting slow-wave sleep [28]. |
| Processed EEG Examples: BIS, SedLine monitors | • Analysis of EEG waveform as surrogate for depth of sedation | • Easy to apply by non-specialists<br>• Provides a preliminary view of sleep data | • Measures sedation depth rather than accurately distinguishing sleep stages<br>• Subject to electrical interference<br>• EMG activity may raise BIS value | • Limited accuracy in predicting sleep quality in postoperative ICU patients [29]. |
| Actigraphy | • Accelerometer-based device (often a wristwatch) | • Easy to use, Low cost and available<br>• Non-intrusive<br>• Allows monitoring over days to weeks | • Measures only motion<br>• A surrogate for measuring sleep-wake states but not sleep stages. | • High sensitivity for sleep detection at 94% but low specificity at 19% [30].<br>• Overestimated total sleep time, sleep efficiency, and the number of awakenings compared to PSG.<br>• The overall agreement between actigraphy and PSG was <65% [31]. |
| Patient Questionnaires e.g. RCSQ, VSH Sleep Scale | • Patients' subjective assessment of their sleep | • Most accessible, least costly | • Recall bias.<br>• Cannot be used in patients with cognitive impairment, delirium, or getting sedative agents<br>• Variable relationship with results of PSG | • RCSQ: High reliability (Cronbach's alpha = 0.90) with a moderate correlation (r = 0.58) to PSG [10].<br>• VSH Sleep Scale: Limited convergent validity (r = 0.39) [32]. |

**Table 2. (Continued)** Summary of methods for sleep assessment in the intensive care unit.

| Instrument | Outcome measure | Advantages | Disadvantages | Validation with PSG |
|---|---|---|---|---|
| Nurse Observation Tools e.g. Sleep Observation Tool | • Direct observation by staff nurses assessing patients' sleep and wake states | • Most accessible, least costly | • Frequent assessment required<br>• May overestimate total sleep time and sleep efficacy than PSG in ICU patients | • One study showed an 81.9% agreement between the Sleep Observation Tool and PSG-identified sleep-wake status [33], while others reported poor correlation with PSG for total sleep time, sleep efficiency, and awakenings [31]. |

AASM: the American Academy of Sleep Medicine, BIS Bispectral Index; EEG: electroencephalogram; EKG: electrocardiography; EMG: electromyography; EOG: electrooculography; ICU: intensive care unit; PSG: polysomnography; RCSQ: Richards-Campbell Sleep Questionnaire; VSH: Verran and Snyder-Halpern Sleep Scale

**Table 3.** Sleep assessment tools in ICU patients based on key sleep quality domains.

| Instrument | Sleep Efficiency | Sleep Latency | Sleep Duration | Wake After Sleep Onset (WASO) |
|---|---|---|---|---|
| Polysomnography (PSG) | Directly measured as total sleep time / total recording time | Time from lights out to first sleep onset | Accurately measured by tracking total sleep time | Determined by identifying wake periods after sleep onset |
| Multichannel EEG and Single-Channel EEG | Estimated from detected sleep epochs / total recording time | Measured from resting state to first sleep stage | Assessed based on EEG-detected sleep periods | Evaluated by detecting wake signals within sleep stages |
| Processed EEG | Indirectly assessed based on BIS values | Monitored by BIS index trends from wakefulness to sleep | Estimated based on time spent in reduced BIS states | Detected by fluctuations in BIS values |
| Actigraphy | Estimated using movement patterns (immobility ratio) | Identified by time from self-reported bedtime to inactivity | Inferred from prolonged inactivity periods | Identified by movement disruptions post-sleep onset |
| Subjective Tools | Patient-perceived sleep quality relative to time in bed | Patient-reported perceived time to fall asleep | Self-reported estimation of total sleep hours | Self-reported awakenings during sleep |
| Nurse Observation Tools | Estimated through observed sleep-wake behavior over time | Assessed by observing time taken to fall asleep | Estimated based on periods of observed sleep behaviour | Noted based on observed awakenings during sleep |

EEG: electroencephalogram; BIS: bispectral index

## OBJECTIVE MEASUREMENT

## POLYSOMNOGRAPHY (PSG)

PSG remains the gold standard for assessing sleep quality and quantity by simultaneous recording of numerous physiological parameters. However, its complexity, high cost, and logistical challenges limit its routine use in ICU settings, where patients often have fragmented sleep that requires 24-hour monitoring [18]. As a result, alternative methods, particularly EEG-based approaches, have gained interest for sleep assessment in critically ill patients [25].

**Standard PSG:**
A standard PSG setup includes 4-6 electroencephalography (EEG) channels to monitor brain activity, electrooculography (EOG) to record eye movements for sleep staging, electromyography (EMG) to track muscle tone in the chin and limbs, electrocardiography (EKG) for heart activity, and respiratory channels to measure airflow and breathing effort, along with pulse oximetry for oxygen saturation levels [34].

The American Academy of Sleep Medicine (AASM) [16] criteria were originally developed to assess sleep in healthy individuals. Illness-related factors often result in atypical EEG patterns, such as frequent awakenings and arousal, disrupted circadian rhythms, and altered sleep architecture (including increased N1 and N2 sleep, decreased N3 and REM sleep). Additionally, the absence of typical N2 markers like K complexes and sleep spindles complicates standard scoring, reducing its effectiveness in critically ill patients [18]. As a result, alternative approaches like spectral analysis of EEG signals have been

explored to better capture the unique sleep characteristics of ICU patients [26].

**EEG-based alternatives in the ICU:**
Given the challenges of using standard PSG in the ICU, two EEG-based approaches have emerged:

1. Single-Channel EEG (SC-EEG): SC-EEG uses electrodes placed on the forehead and mastoid to provide a portable, non-invasive method for measuring total sleep time (TST), N2, N3, frontal slow-wave activity, and REM sleep, though it shows poor agreement in detecting N1 sleep [35]. While effective in healthy adults, SC-EEG performs less reliably in ICU patients due to frequent sleep stage transitions. In a small proof-of-concept study [28], SC-EEG was compared to full PSG in five critically ill adults (two with mechanical ventilators) and five healthy adults. Spectral analysis revealed that SC-EEG had a sensitivity of 0.68 and a specificity of 0.59 for detecting slow-wave sleep. Although promising, SC-EEG has limitations in ICU settings due to its narrow scope and is more suitable for research purposes.

2. Multichannel EEG: Multichannel EEG expands on SC-EEG by using additional electrodes to capture detailed sleep signals, including sleep spindles, K complexes, and slow waves. Studies have validated multichannel EEG against PSG in healthy adults [27], demonstrating better portability and tolerability for ICU patients compared to full PSG, while still providing more comprehensive sleep data. However, further validation is needed in critically ill populations [36,37].

**Example of studies in ICU patients:**
Several studies have evaluated sleep in ICU patients using PSG and alternative methods:

- Ambrogio et al.[26] reported poor interobserver reliability for R&K scoring in ICU patients, particularly for stages N1 and N2, though it performed better for REM sleep. Spectral analysis of EEG significantly improved reliability, suggesting that automated approaches may yield more consistent measurements in critically ill patients.
- Gehlbach et al.[38] evaluated EEG and circadian rhythms over a 24-hour period but could not detect normal sleep characteristics in ICU patients, highlighting the limitations of traditional sleep analysis methods in this population.
- Drouot et al.[39] introduced the concepts of "atypical sleep" and "pathologic wakefulness" in non-sedated, mechanically ventilated patients. They developed a novel method using EEG analysis (focusing on peak EEG frequency, EEG reactivity, and power spectra) that demonstrated high sensitivity and specificity for detecting atypical sleep in ICU patients, emphasizing the need for specialized criteria in this setting.

In addition to these studies, novel scoring systems, such as those developed by Watson et al. [18], combine behavioral observations with EEG markers, achieving high interrater reliability. These systems provide more accurate assessments of sleep in ICU patients, who often exhibit non-standard EEG patterns due to sedation, critical illness, and environmental factors.

**Summary:**
While PSG remains the gold standard for sleep assessment, its limitations in the ICU necessitate adaptations such as spectral analysis and the development of new scoring systems tailored to critically ill patients. These innovations offer the potential to improve our understanding of sleep patterns in ICU settings, leading to more targeted interventions that could enhance recovery and patient outcomes.

## PROCESSED EEG SYSTEMS

Processed EEG systems, such as the Bispectral Index (BIS) (Medtronic, Minneapolis, MN, USA) and SedLine monitors, analyze raw EEG waveforms to evaluate anesthesia depth. The BIS monitor processes one- or two-channel EEG data from a single hemisphere, using power and phase information across α, β, δ, and θ frequency bands. BIS values range from 0 to 100, with 40–60 representing an optimal hypnotic state for anesthesia [40,41]. In contrast, the newer SedLine monitor provides a Patient State Index (PSI) by assessing spatial and temporal EEG gradients using four channels from both hemispheres. PSI values also range from 0 to 100, with 25–50 indicating the optimal range for general anesthesia [40,41].

Processed EEG systems do not require continuous attendance by a sleep technician, making them a more practical option in ICU settings compared to PSG. The sensors are easy to apply and can provide an overview of sleep quantity. However, like traditional EEG, BIS is susceptible to electrical interference and increased EMG activity, which may compromise signal quality [41].

Despite its practicality, BIS has notable limitations in ICU settings. It primarily measures sedation depth rather than accurately distinguishing sleep stages, making it less reliable for sleep assessment. BIS scores do not directly translate to accurate sleep staging. In non-sedated ICU patients, BIS scores correlate with neurological function, where higher scores indicate better neurological status [42]. However, in patients with conditions like stroke or traumatic brain injury, lower BIS values may not reliably reflect sleep quality. Additionally, BIS scores can be influenced by delirium, further complicating the interpretation of sleep states [43].

**Example of studies in ICU patients:**

- Nicholson et al. [44] monitored overnight sleep patterns in 27 recovering ICU patients aged 15 to 82 years using BIS and submental EMG. Sleep stages were categorized based on BIS values: wake (>85), light sleep (60–85), slow-wave sleep (<60), and REM (>60) with distinct EMG changes. The study concluded that none of the patients experienced completely normal sleep. Twelve exhibited cyclical sleep patterns, three had no sleep, and twelve showed abnormal sleep patterns, with some appearing in a REM-like state despite high BIS scores and low levels of consciousness.
- Giménez et al. [45] assessed the reliability and feasibility of using BIS for sleep monitoring. Complete PSG recordings were obtained at baseline and after 40 hours

of sleep deprivation. The study found a strong correlation between the BIS index and the hypnogram, with BIS values decreasing progressively as sleep deepened and rising during REM sleep.

- Sirilaksanamanon et al. [29] monitored 33 postoperative ICU patients using both BIS and PSG on the first postoperative day. The BIS index was highest during the awake state (85.1, 95% confidence interval (CI), 83.2–87.0) and gradually declined with deepening NREM sleep stages: stage I (78.5, 95% CI, 76.6–80.4), stage II (73.3, 95% CI, 71.4–75.2), and stage III (63.2, 95% CI, 61.2–65.1). BIS values increased again during REM sleep (75.9, 95% CI, 73.7–78.1). The area under the curve (AUC) for BIS in predicting good postoperative sleep quality was 0.65.
- Vacas et al. [46] evaluated SedLine against PSG in three healthy subjects in a sleep laboratory. The study found an overall agreement of 75% for sleep-wake states, with 67% agreement for wake, 77% for NREM, and 89% for REM. However, agreement for individual sleep stages was low, with only 29% for stage N1 and 6% for stage N3.

**Summary:**
BIS and other processed EEG-based monitors offer practical advantages over PSG in ICU settings by not requiring a technician and being relatively easy to use. However, they remain primarily indicators of sedation depth rather than reliable tools for detailed sleep staging. Current evidence suggests that while BIS may help with general sleep-wake assessment, it lacks the accuracy needed for sleep stage monitoring in critically ill patients. Further high-quality studies are necessary to validate the use of processed EEG against PSG-defined sleep stages in ICU patients.

## ACTIGRAPHY

Actigraphy is a non-invasive, accelerometry-based method used to monitor movement, typically worn on the wrist. It estimates sleep and wake states by detecting gross body movements and has gained popularity over the years due to its affordability, ease of use, and ability to be employed across various age groups, including children. Actigraphy has demonstrated high sensitivity of 0.965 but low specificity of 0.329 when validated in sleep laboratory settings [47], meaning it often detects sleep but may inaccurately classify wakefulness as sleep.

In ICU patients, who are frequently immobilized or sedated, actigraphy tends to overestimate sleep duration. Studies comparing actigraphy with PSG have shown that actigraphy tends to overestimate total sleep time and sleep efficiency while detecting more nighttime awakenings compared to PSG [48]. Additionally, actigraphy often reports more awakenings than nurse observations or patient questionnaires [48]. Current research on actigraphy in ICU settings is constrained by small sample sizes and brief measurement durations, highlighting the need for studies involving larger patient cohorts and extended observation periods.

**Example of studies in ICU patients:**

- Beecroft et al. [31] studied 12 stable, mechanically ventilated ICU patients over one night. Actigraphy overestimated total sleep time (5.73 hours versus 3.1 hours with PSG), sleep efficiency (78.1% versus 41.9%), and the number of awakenings (58.5 versus 40) compared to PSG. The study's limitations included a small sample size and single-night observation.
- Van der Kooi et al. [30] evaluated sleep in seven post-cardiothoracic surgery patients. Actigraphy demonstrated high sensitivity for sleep detection at 94% but low specificity at 19%. The correlation with PSG for detecting awakenings was significant ($r = 0.76$). However, the study was limited by a small sample size.
- Delaney et al. [49] studied 80 ICU patients, including both mechanically ventilated (24%) and non-ventilated (76%) individuals. Actigraphy demonstrated a moderate overall agreement with PSG in identifying sleep and wake states (69.4%; $K = 0.386$, $p < 0.05$) in an epoch-by-epoch analysis, with moderate sensitivity (65.5%) and specificity (76.1%).
- Hsu et al. [50] randomized 60 medical ICU patients to receive either back massage or usual care over three nights. Actigraphy recorded a higher total sleep time of 5.9 hours compared to 4.0 hours reported by nurse observations, highlighting discrepancies between actigraphy and subjective measures.
- Kamdar et al. [51] compared wrist and ankle actigraphy in 34 patients and found poor agreement between the two measurement sites, indicating that wrist and ankle actigraphy should not be used interchangeably.

**Summary:**
Actigraphy is a practical and relatively objective tool for monitoring sleep in ICU patients, but it often overestimates sleep compared to PSG. Although it demonstrates high sensitivity, its low specificity limits accuracy, particularly in immobilized or sedated patients. Further research with larger sample sizes, extended study durations, and specialized devices designed for critically ill patients is needed to improve its reliability.

## SUBJECTIVE MEASUREMENT

## PATIENT QUESTIONNAIRES

Patient questionnaires assess sleep quality from the patient's perspective. In the ICU setting, ten different sleep questionnaires have been reported, with the Richards-Campbell Sleep Questionnaire (RCSQ) being the most widely used and validated against PSG. The RCSQ has shown high internal consistency reliability with a Cronbach's alpha of 0.9 [10].

**Examples of sleep questionaires use in ICU:**

- Richards-Campbell Sleep Questionnaire (RCSQ) [10] The RCSQ is a five-item questionnaire designed to comprehensively assess sleep by measuring perceived sleep depth, sleep latency (time to fall asleep), frequency

of awakenings, ease of returning to sleep, and overall sleep quality. Each item is rated on a 0–100 visual analog scale, where higher scores signify better sleep. The overall sleep quality score is calculated as the average of the five item scores. It has been translated into multiple languages, including Arabic [52], Chinese [53], German [54], Japanese [55], Portuguese [56], and Thai [57] making it accessible to diverse populations. While easy to use, the RCSQ is suitable only for patients who are cognitively intact and able to respond. A study from Australia [58] explored the interrater reliability between patients and nurses, reporting moderate agreement.

- Verran and Snyder-Halpern Sleep Scale (VSH) [59] This visual analog scale, consisting of 9 to 15 items depending on the version, was originally designed for healthy individuals and has been evaluated in ICU patients in multiple studies [50,60,61], with one study showing limited convergent validity (r = 0.39) [32].
- Pittsburgh Sleep Quality Index (PSQI) [62] The PSQI evaluates overall sleep quality over a one-month period and was initially developed for psychiatric populations. It is not designed to detect daily sleep variability and has not been validated against PSG in ICU settings.
- Coronary Care Unit Questionnaire (CCUQ) [63] The CCUQ is a 9-item questionnaire designed to evaluate sleep in coronary care units. A validation study involving 99 participants demonstrated acceptable internal consistency reliability (Cronbach's alpha = 0.69) and a moderate correlation with sleep efficiency measured by PSG (r = 0.518).
- Numeric Rating Scale for Sleep (NRS-Sleep) Rood et al.[64] conducted a comprehensive validation study of the NRS-Sleep, involving 194 participants in Phase 1 and 1,603 in Phase 2. The tool demonstrated a strong correlation with the RCSQ (r = 0.88, $p < 0.01$), and an NRS score >5 was established as the threshold for good sleep quality, with a sensitivity of 83% and a specificity of 79%.

**Summary:**
Patient perception of sleep quality is a crucial aspect for sleep clinicians and researchers to assess. However, many studies using sleep questionnaires in ICU patients fail to report the validity or reliability of the tools employed. Reliable instruments such as the RCSQ, VSH, CCUQ, or NRS-Sleep should be utilized, with clear justification for their selection. The use of sleep diaries in critically ill patients is often limited by their cognitive and physical impairments. Therefore, combining self-assessment with objective sleep assessments or observational methods is recommended for a more comprehensive evaluation.

## NURSING OBSERVATION TOOLS

Nursing observation tools serve as a practical first step for assessing sleep quality in ICU patients, raising awareness among nurses about the importance of sleep in patient care. While not as accurate as PSG, nursing observation can still provide valuable insights into sleep patterns when applied correctly.

**Examples of nurse observation tools used in ICU:**

- Sleep Observation Tool (SOT) [33] developed by Edward and Schuring specifically for ICU settings, the SOT involves observing patients' sleep every 15 minutes. When used correctly, it identifies sleep with 81.9% accuracy compared to PSG. The SOT was used in a large multi-center observational study by Litton et al. [65] (n = 538) to evaluate sleep disruption in ICU patients. It was also utilized as an outcome measure in two intervention studies by Dennis et al. [66] and Olsen et al. [67], which investigated the impact of enforced quiet time on sleep. Due to the impracticality of observing patients every 15 minutes throughout the night, modifications have been made. For instance, Dennis et al. used the SOT to observe sleep seven times daily instead of at 15-minute intervals.
- Patient Sleep Behavior Observation Tool (PSBOT) The PSBOT, used primarily in pediatric settings [68], classifies sleep into four stages: awake, drowsy, paradoxical (REM), and orthodox (non-REM) sleep. It has demonstrated moderate convergent validity for measures such as wake after sleep onset and sleep latency [32].
- Other nurse-reported sleep measures
  - Beecroft et al. [31] developed a basic questionnaire consisting of two questions: 1) "How many hours did your patient sleep?" and 2) "How many times did your patient wake?" However, this approach showed no significant correlation with PSG-measured sleep.
  - Ibrahim et al. [69] utilized a visual observation approach in which ICU nurses recorded indicators such as closed eyes, reduced motor activity, and minimal interaction with the environment. This method also lacked reported criterion validity or reliability against PSG.

**Summary:**
Nursing observation tools provide a practical approach to assessing sleep quality in ICU patients, especially when patient participation is not possible. While they offer valuable insights and raise awareness about the importance of sleep, these methods often overestimate sleep compared to PSG, as immobilized patients or those who often close their eyes while awake might be mistakenly judged as asleep. Despite these limitations, nursing observations remain useful for monitoring sleep patterns and improving patient care in critically ill populations.

## NON-TRADITIONAL METHODS

Nontraditional methods for evaluating sleep include advanced physiologic-based techniques, which have not yet been thoroughly tested in this population. Functional imaging modalities, such as functional MRI (fMRI) and positron emission tomography [70,71], offer the ability to record specific physiologic parameters like central nervous system (CNS) blood flow and metabolism. However, these methods pose significant challenges, including high costs and the logistical and safety risks associated with transporting critically ill patients for imaging. While fMRI has been used in disorders of consciousness in the

critically ill, it has not been directly applied to sleep assessment. Emerging approaches like microRNA analysis [72] show promise as potential serum biomarkers for detecting or predicting poor sleep quality, but their clinical application, particularly in the ICU, remains untested. Together, these newer physiologic-based methods represent innovative but as-yet-unproven tools in sleep evaluation for critically ill individuals.

## IMPLICATION TO CLINICAL PRACTICE

To guide clinical practice in selecting the most appropriate sleep assessment tools, it is important to consider the patient's condition and the intended purpose of monitoring. For routine ICU sleep screening, self-report questionnaires such as the Richards-Campbell Sleep Questionnaire (RCSQ) are recommended for patients who can provide input, as they offer a simple and direct evaluation of perceived sleep quality. In cases where patients are unable to self-report, alternative methods such as actigraphy or nurse observation tools provide practical, non-invasive solutions for monitoring sleep patterns. However, for research purposes or when a more detailed clinical evaluation of sleep architecture is required, multichannel EEG or PSG should be utilized, as these methods offer comprehensive insights into sleep stages and disturbances, though their feasibility is often constrained by cost and operational complexities.

## FUTURE RESEARCH SUGGESTED

Future research should prioritize the development and validation of simplified EEG-based tools that can accurately assess sleep architecture in critically ill patients while ensuring ease of implementation in ICU settings. Additionally, it would be beneficial to investigate the long-term impact of ICU-related sleep disturbances on cognitive function and quality of life after discharge, as well as explore effective strategies to promote sleep efficiency in the ICU environment. Longitudinal studies could provide valuable insights into the extent to which improved sleep assessment and targeted management strategies can contribute to better patient outcomes and overall recovery.

## CONCLUSION

Sleep is a crucial process for restoring normal bodily functions and promoting recovery, yet ICU patients often experience poor sleep, leading to cognitive decline and delirium. Currently, reliable measures of sleep quality in the ICU are limited, indicating the need for more research in this area. Objective assessment tools mainly depend on EEG patterns that reflect the sleep-wake cycle of healthy individuals, but these methods are costly and difficult to apply in an ICU setting. Subjective assessments, while helpful, can be inconsistent or unattainable in critically ill patients. To address these challenges, it is essential to develop reliable, easy-to-use, objective tools specifically designed for ICU patients, alongside subjective assessments, to better evaluate and enhance sleep quality. Establishing effective methods for assessing and improving sleep in the ICU is a critical step toward optimizing patient outcomes [73].

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