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Correlation Between Sleep Continuity and Patient-Reported Sleep Quality in Conscious Critically Ill Patients at High Risk of Reintubation: A Pilot Study

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OBJECTIVES: It is well-established that sleep quality of ICU patients is poor, with sleep being highly fragmented by multiple awakenings. These sleep disruptions are associated with poor outcomes such as prolonged weaning duration from mechanical ventilation. Polysomnography can measure sleep continuity, a parameter associated positively with outcomes in patients treated with noninvasive ventilation, but polysomnography is not routinely available in all ICUs, and simple means to assess sleep quality are needed. The Richards-Campbell sleep questionnaire (RCSQ) assesses sleep quality in ICU patients but is difficult to administrate in patients who are not fully awake, and a simpler sleep numeric rating scale (sleep-NRS) has been proposed as an alternative. We here investigated the relationships between sleep continuity and patients-reported sleep quality.

DESIGN: Single-center retrospective study.

SETTING: Medical ICU of Poitiers University Hospital.

PATIENTS: Seventy-two patients were extubated from mechanical ventilation and at high risk of reintubation.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: We analyzed 52 previously recorded polysomnographies in nonsedated and conscious ICU patients. Sleep was recorded the night after extubation. Sleep continuity was measured using an automated scoring algorithm from one electroencephalogram (EEG) channel of the polysomnography. Patient-reported sleep quality was assessed using RCSQ and sleep-NRS. Sleep continuity could be calculated on 45 polysomnographies (age: 68 [58–77], median [25th–75th]) RCSQ (62 [48–72]) and sleep-NRS (6.0 [5.0–7.0]) were obtained in 21 patients and 34 patients, respectively. Our results show a significant correlation between sleep continuity and sleep-NRS ($p = 0.0037$; $\rho = 0.4844$; $n = 34$) but not with RCSQ score ($p = 0.6732$; $\rho = 0.1005$; $n = 20$).

CONCLUSION: Sleep continuity correlates with patient-reported sleep quality assessed using sleep-NRS and may capture the refreshing part of sleep. Sleep-NRS can be easily administered in ICU patients. Sleep continuity and sleep-NRS are simple tools that may prove useful to evaluate sleep quality in ICU patients.

KEYWORDS: algorithm; intensive care unit; polysomnography; questionnaire; sleep quality

In ICUs, a majority of patients experience severe sleep disruption due to continuous care, a noisy environment, and high light levels (1). These sleep alterations have serious negative consequences, including weaning phases of longer duration and higher mortality (1).

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KEY POINTS

Question: Assessing sleep quality in critically ill patients is challenging. Sleep continuity is a promising readout that needs to be confirmed.

Findings: In this single-center retrospective study, we report a significant correlation between sleep continuity, automatically calculated from the electroencephalogram, and patient-reported sleep quality assessed using a recently validated sleep quality numeric rating scale (sleep-NRS).

Meaning: Sleep continuity likely captures the refreshing part of sleep. The sleep-NRS seems to be an interesting tool, easy to administrate, in assessment of patient-reported sleep quality.

Quantifying sleep—whether objectively measured sleep continuity or patient-reported sleep quality—is especially challenging in critically ill patients. Polysomnography gives access to total sleep time (TST), sleep stage composition, and sleep fragmentation quantification (i.e., number of arousals and awakenings per hour of sleep). However, polysomnography is particularly challenging because it requires dedicated equipment and sleep technicians to install electroencephalogram (EEG) electrodes. Polysomnography also allows calculation of sleep continuity, which has been associated with outcomes in ICU patients (2). Two advantages of sleep continuity are that it can be measured by processing a single EEG channel instead of full polysomnography and that it can be calculated automatically (3).

Sleep quality can also be assessed by sleep questionnaires. The Richards-Campbell sleep questionnaire (RCSQ) is a validated questionnaire and has been largely employed in ICUs. However, RCSQ is difficult to administrate in patients who are not fully awake, and it is considered reliable in only around 50% of ICU patients (4). To overcome this limitation, a simpler sleep-NRS has been proposed as an alternative (5).

Because sleep continuity has been correlated with critical-illness outcome (2), we investigated the relationships between sleep continuity as measured from EEG recordings and patient-reported sleep quality using either RCSQ or sleep-NRS.

METHODS

Study Design and Patients

This article reports on a new analysis of a previously published cohort (6). The study was performed between January 2016 and January 2019 at the medical ICU of the University Hospital of Poitiers in France to investigate the role of sleep quality on respiratory failure after extubation (6). Patients at high risk of extubation failure (> 65 yr, or with any underlying cardiac or lung disease, or intubated > 7 d) were included. Patients intubated less than 24 hours, with central nervous or psychiatric disorders, continuous sedation, neuroleptic medication, or uncooperativeness were excluded. Sleep was assessed by polysomnography just after extubation including the night. The main objective of this study was to compare sleep between patients who developed postextubation respiratory failure or required reintubation and others. The study was approved by the independent ethics committee of Poitiers (CPP Ouest III) on November 24, 2015, with the registration number 2015-A01726-43 and with the following title: "Sleep Quality in ICU Patients at High Risk of Extubation Failure." This study was registered at http://www.clinicaltrials.gov (NCT02911506). Written consent from patients and/or their next of kin was given prior being included in this study. All procedures of this study were followed in accordance with the ethical standards of the responsible institutional committee on human experimentation of Poitiers (CPP Ouest III) and with the Helsinki Declaration of 1975.

Sleep Recordings

Polysomnographies were performed over 17 hours (start at 3 PM, end at 8 AM the next day) using a Dream° polysomnograph (Medatec France, Ablis, France). Polysomnography consisted of six EEG channels (F4-A1, F3-A2, C4-A1, C3-A2, O2-A1, and O1-A2), one chin electromyogram and two electrooculograms recorded at 200 Hz sampling rate.

Patients' Sleep Assessments

The RCSQ is a scale based on five items: sleep depth, sleep latency, sleep efficiency, return to sleep, and global sleep quality. As demonstrated by Frisk and Nordstrom (4), the patient's environment (noise, etc.) influences sleep quality. A sixth item has therefore been included to take this parameter into account. Each item is scored by the patient from 0 to 100. The final RCSQ score is the mean of the six items (with score close to 100 representing good sleep).

The sleep-NRS is a previously validated one-dimensional visual analog scale assessing sleep quality (5). The patient is asked to determine the sleep quality of the previous night between 0 ("worst sleep night") and 10 ("best sleep night"). The sleep-NRS is very similar to question 5 of the RCSQ ("global sleep quality"). All patients having completed the RCSQ also completed the sleep-NRS.

Sleep Continuity

Sleep continuity was automatically calculated using a validated automated scoring algorithm. This algorithm processed a single EEG channel (C3-A2) to calculate sleep continuity (3). Sleep continuity was defined by the proportion (%) of sleep time spent in sleep episodes lasting more than 10 minutes (2). A minimum of 50 min of TST was required to calculate sleep continuity. The more time spent in long sleep episodes, the higher the sleep continuity.

Statistical Analysis

Continuous variables are expressed as median [interquartile range]. Correlations between continuous variables were tested using the Spearman correlation test ($p < 0.05$ for significance).

RESULTS

Patients

Seventy-two patients were included. Among the 52 patients who had polysomnography recording after midnight, 12 (23%) developed postextubation respiratory failure and 8 (15%) required reintubation. Median [interquartile range] duration of mechanical ventilation before extubation was 9 days [4–16] and median duration of sedation before polysomnography was 3 days [2–9]. All patients were maintained in the ICU for ongoing critical illness; no patients were kept in the ICU per protocol. Sequential Organ Failure Assessment score at time of sleep recording (median [25th–75th]) was 3 [2–4]. Simplified Acute Physiologic Score II at admission (median [25th–75th]) was 48 [36–62]. Median TST was 3.2 hours [2.0–4.4] in patients who developed postextubation respiratory failure versus 2.0 hours [1.1–3.8] in those who were successfully extubated ($p = 0.34$). TST, durations of deep and Rapid Eye Movement sleep stages did not differ between patients who required reintubation and the others. No reintubation occurred during the polysomnography.

Sleep Assessment

Sleep continuity could be calculated on 45 polysomnographies, (age: 68 [58–77], median [25th–75th]), after excluding seven polysomnographies due to artifacts or loss of raw data or insufficient sleep (**Fig. 1**). Eleven patients (24%) displayed atypical sleep on visual scoring.

The RCSQ (62 [48–72]) and sleep-NRS (6 [5–7]) were completed in 21 patients and 34 patients, respectively (Fig. 1). Among the latter, 3 patients (9%) had a positive score on the confusion assessment method for the ICU scale. The reasons precluding total completion of RCSQ were somnolence,

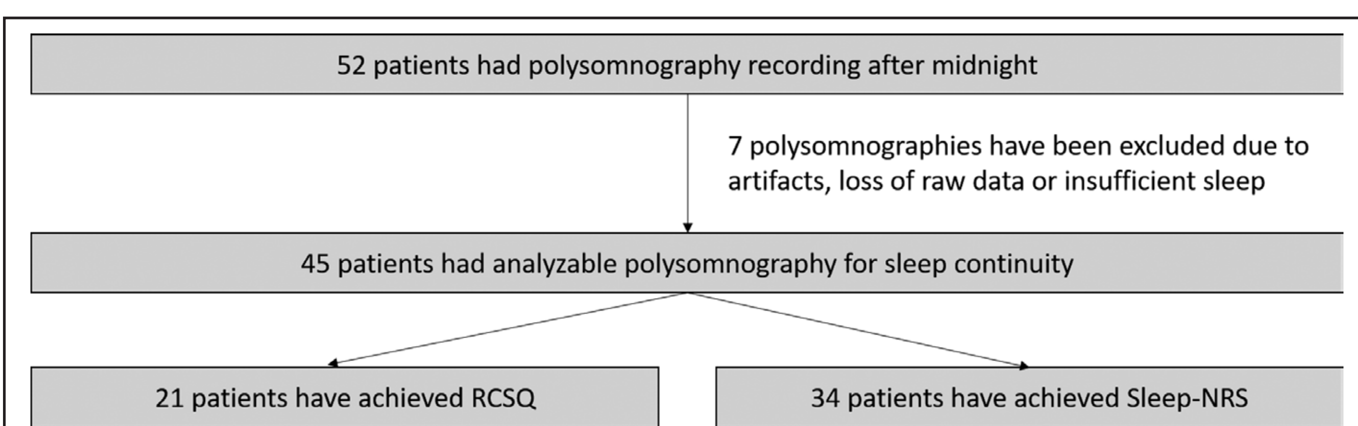

Figure 1. Flowchart of the patients. Note that the sleep numeric rating scale (sleep-NRS) is very close to the fifth item of the Richard-Campbell Sleep Questionnaire (RCSQ); all 21 patients but one who completed the RCSQ also completed a sleep-NRS score.

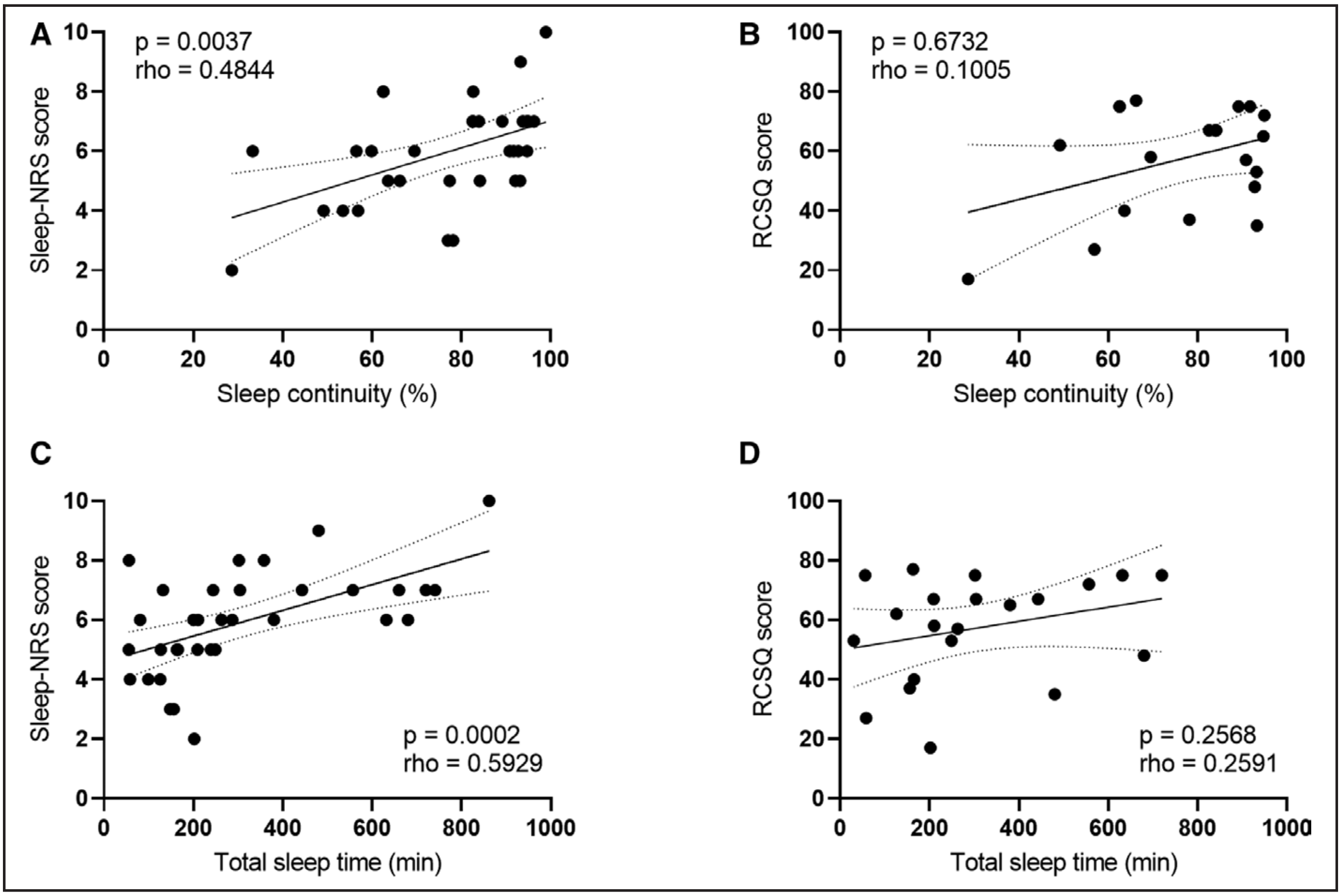

Figure 2. Patient-reported sleep quality and objective sleep parameters (sleep continuity and total sleep time (TST) calculated by automated sleep scoring). **A**, Sleep continuity is correlated with patient-reported sleep quality assessed by sleep numeric rating scale (sleep-NRS) ($p = 0.0037$, rho = 0.4844, $n = 34$, Spearman correlation test). **B**, Sleep continuity is not correlated with Richard-Campbell Sleep Questionnaire (RCSQ) score ($p = 0.6732$, rho = 0.1005, $n = 20$). **C**, TST is correlated with sleep-NRS ($p = 0.0002$, rho = 0.5929, $n = 34$), but not with RCSQ score (**D**, $p = 0.2568$, rho = 0.2591, $n = 21$).

exhaustion, lack of attention, difficulty to understand or to quantify the symptoms or refusal to answer last items, and lack of cooperation. All but one of the 21 patients who completed the RCSQ also completed a sleep-NRS score. Sleep-NRS and RCSQ were correlated ($p = 0.0281$; $\rho = 0.4904$; $n = 20$; Spearman correlation test).

Median [25th–75th] sleep continuity was 82.6% [63.6–92.0]. Median sleep continuity (median [25th–75th]) was not different in patients with and in those without atypical sleep (77.4% [65.3–90.9] and 82.6% [63.6–92.0], respectively; Mann-Whitney *U* test, $p = 0.55$).

Our results show a significant correlation between sleep continuity and sleep-NRS ($p = 0.0037$; $\rho = 0.4844$; $n = 34$; Spearman correlation test; **Fig. 2*A***), but not between sleep continuity and RCSQ score ($p = 0.6732$; $\rho = 0.1005$; $n = 20$; Spearman correlation test; **Fig. 2*B***).

Our results also show a significant correlation between sleep-NRS and TST measured by the algorithm ($p = 0.0002$; $\rho = 0.5929$; $n = 34$; Spearman correlation test; **Fig. 2*C***), but not between RCSQ score and TST ($p = 0.2568$; $\rho = 0.2591$; $n = 21$; Spearman correlation test; **Fig. 2*D***). After randomly deleting 13 values to obtain a total of 21 sleep-NRS values, the significant difference still persists, whether between sleep continuity and sleep-NRS ($p = 0.0003$; $\rho = 0.7115$; $n = 21$; Spearman correlation test), or between TST and sleep-NRS ($p < 0.0001$; $\rho = 0.7833$; $n = 21$; Spearman correlation test).

DISCUSSION

Sleep disruptions in critically ill patients are a real issue for ICU caregivers, and assessing sleep quality remains technically and medically difficult. There is a strong need for new tools to quantify sleep alterations. Here, we confirm that measuring sleep continuity using an automated scoring algorithm could be of interest to assessment of sleep in ICU.

Our results show that sleep continuity was correlated to the sleep quality reported by patients using sleep-NRS. Sleep continuity has also been correlated with critically illness outcomes (2). Our results are in line with another study showing that EEG-based measurement of sleep quality using automated analysis correlated with patient-reported sleep quality assessed with the Pittsburgh sleep quality index in a general population (7). Our results extend this study to ICU patients, for whom standard American Academy of Sleep Medicine sleep scoring rules are unreliable (8, 9). In addition, our automated algorithm adds an innovative upgrade to the technology by processing EEG in real time. To our knowledge, this is the first algorithm to score sleep on the fly (3). On the other hand, sleep continuity was not correlated with RCSQ. This contrasts with several studies showing that RCSQ was correlated with the sum of N2, N3, and R stages or to sleep efficiency (10). However, one study found a weak correlation ($\rho = 0.123$) between EEG-based measures of sleep quality and RCSQ score (11). One reason for our results might be the lower number of patients able to complete RCSQ. The results of this pilot study suggest that sleep continuity might be a reliable and objective surrogate of patient-reported sleep quality.

Our study has several limits. First, the number of patients included is small, specifically the number of patients able to complete RCSQ. In addition, our study is limited to a regional dataset and is retrospective. However, sleep recording in ICU is challenging and the availability of a miniaturized polysomnograph should facilitate relevant studies (3). Subjective testing can be complicated to carry out. RCSQ or sleep-NRS might be less reliable in ICU patients than in the general population. RCSQ is particularly difficult to administrate in delirious patients (4). Sleep-NRS has the advantage of including only one visual analog scale. This questionnaire test might be more adapted in delirious patients than RCSQ but dedicated studies are necessary to determine whether sleep-NRS is reliable in these patients.. Another weakness is the absence of nasal airflow recording, which precluded the identification of sleep-disordered breathing (SDB). This is a limitation because SDB might be a major potential contributor to sleep discontinuity, especially in a cohort of patients greater than 65 with cardiopulmonary disease. The lack of limb EMG also precluded assessment of sleep fragmentation provoked by periodic limb movements.

Our results show a clinical interest due to a correlation between EEG-based measurement of sleep continuity and patient-reported sleep quality. Consistent with the theory of Bonnet (12), it is well-established that sleep episodes have to last a minimum of 10 minutes to be restorative. Our results are in line with this theory since patients with higher sleep continuity reported higher sleep quality. This suggests that sleep continuity may capture a relevant physiologic part of sleep. Intuitively, it is easily conceivable that one long bout of 50 minutes of sleep and five additional short bouts of 2 minutes might be more refreshing that than six bouts of 10 minutes each, although time spent asleep and fragmentation are identical (60 min and six sleep episodes) in the two situations (2).

In conclusion, our results showed that automatically calculated sleep continuity likely captures the refreshing part of sleep. Sleep-NRS is easier to administrate than RCSQ in ICU patients and could be easily implemented to monitor sleep quality in routine clinical practice in ICU. Sleep continuity and sleep-NRS may also prove useful as surrogate markers of sleep quality when testing the efficacy of strategies aimed at improving sleep in ICU patients.

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