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Original Article

Sleep in Elderly Patients under Prolonged Mechanical Ventilation: An Observational Study

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SUMMARY

Introduction: Sleep typically becomes more disturbed with age. Similarly, the quantity and quality of sleep in patients undergoing critical care in the intensive care unit is usually disrupted. The aim of the current study was to evaluate the sleep conditions of elderly adults with prolonged mechanical ventilation (PMV) in a respiratory care center (RCC).

Methods: It was a three-stage prospective observational study, which aimed to evaluate the patient's subjective sleep quality, their circadian rhythm, and objective sleep parameters. The Richards-Campbell sleep questionnaire (RCSQ), 24-hour body temperature measurements, and 24-hour polysomnography (PSG) were used to assess these features, respectively in patients undergoing PMV therapy.

Results: Eight elderly participants completed 30 RCSQ surveys, and the average total score was 52.9 ± 20.3 . Among the 19 elderly subjects who had their 24-hour body temperatures measured, only 21.1% were assessed as having a normal body temperature circadian rhythm. A total of 6 elderly patients underwent 24-hour PSG and their mean recording time was 22.8 ± 0.8 hours. The total sleep time was 411.1 ± 247.6 minutes, and the time spent in sleep stages N1, N2, N3 and REM was 23.1%, 70.1%, 3.3% and 3.5% of total sleep, respectively. The majority of sleep ($61.5 \pm 14.5\%$ of total sleep) occurred intermittently during the day as opposed to at night. Sleep efficiency was $33.7 \pm 26.9\%$ at night.

Conclusions: Elderly patients receiving PMV in the RCC presented with poor subjective sleep quality, disrupted circadian rhythms, and disturbed and fragmented sleep.

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1. Introduction

Human life expectancy has increased around the world, and as many as 20 million people are now admitted to intensive care units (ICUs) to receive mechanical ventilation (MV) per year.¹ Among them, approximately 5.4–14% of patients receive prolonged mechanical ventilation (PMV). Compared with patients who are successfully weaned from MV, patients who receive PMV have reduced survival.^{2,3} Although there are multiple factors associated with PMV, it's known that it is more difficult to wean older patients from MV.^{4,5}

Sleep is a normal recuperation process and its importance for critically ill patients has attracted attention.⁶ Sleep deprivation is associated with impaired immune function, increased cardiovascular events, disturbed endocrine function, and is usually accompanied by delirium.^{7,8} Just one night of sleep loss reduces inspiratory muscle endurance and ventilatory response to hypercapnia and hypoxemia in healthy subjects, and can reduce the forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) in patients with chronic obstructive pulmonary disease.^{9–11} Sleep deprivation is a factor associated with PMV, while better sleep is associated with pa-

tients who are successfully weaned from MV.^{4,12}

Sleep patterns change with age; sleep duration, slow wave sleep, and sleep efficiency decrease, while sleep fragmentations increase.^{13–15} Sleep homeostasis and circadian rhythms are also altered in the elderly as they typically change with age. This can lead to advanced circadian phases and less sleep consolidation when environmental conditions change.

When patients are admitted to the ICU, their sleep may be further disturbed.¹⁶ The quantity and quality of sleep in ICU patients is disrupted; sleep duration, slow wave sleep, REM sleep, and sleep efficiency are decreased, while sleep fragmentation and arousal are increased.^{17–22} This can be due to the noise, lighting, patient-care activities, MV, medications, and the disease itself.^{18,19,23} If the patients are treated with PMV, even if they are discharged from the ICU to a specialized weaning unit (SWU) for further weaning from MV, sleep problems will continue to be troublesome.^{24,25}

We understand that patients in ICUs and the elderly population both have similar poor sleep conditions. However, to the best of our knowledge, there has not been a study that's focused on the sleep status of elderly patients with PMV in ICUs or SWUs. Therefore, we conducted a series of prospective observational studies, which evaluated subjective sleep quality, circadian rhythms, and objective sleep parameters to broadly evaluate the sleep condition of the elderly in a SWU.

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2. Materials and methods

2.1. Participants

The current investigation was a prospective observational study. We enrolled patients at a 13-bed respiratory care center (RCC) in MacKay Memorial Hospital, an academic tertiary hospital in Taipei, Taiwan, from February 2018 to July 2018. The RCC is a SWU that treats patients (including medical or surgical patients) who have received MV for more than 21 days and have stable clinical conditions. The RCC is a multi-bed room without partitions, and there is a nursing station in the center of the unit. Its environment is similar to that of the ICU. Ventilators and monitors are stationed near the head of each bed. From 21:00 to 06:00, the lights above the beds are dimmed but they remain bright at all other times of the day.

Only patients who met the inclusion criteria and provided informed consent were enrolled in the current study. The inclusion criteria were: (a) conscious and non-sedated adult patients, (b) generally stable condition (heart rate 60 to 120 beats per minute, blood pressure 100/50 to 150/90 mmHg, respiratory rate < 25 times per minute, and SpO₂ > 90% when the oxygen concentration was < 50%), (c) body temperature < 38 °C and no use of antipyretics. Patients with delirium or who could not cooperate with the measurements were excluded. Patients > 65 years old were defined as the elderly group, while all others were defined as the young group. Demographic and clinical information was collected from the patient's medical records. This study was approved by the Institutional Review Board of MacKay Memorial Hospital (approval no. 17MMHIS177e).

2.2. Self-reported sleep quality

The Richards-Campbell sleep questionnaire (RCSQ) was used to evaluate the patient's subjective sleep quality.²⁶ The RCSQ is a 100 mm visual analogue scale, from 0 to 100, which uses five questions to assess sleep perception in ICU patients, including sleep depth, sleep onset latency, number of awakenings, time spent awake, and overall sleep quality. The average of the five items in the RCSQ was used as the total sleep score, and the higher the score the better the sleep. In the morning, the participants were asked to fill out the questionnaire about their previous night's sleep, with the help of the nurses. If the participants remained in the RCC and met the inclusion criteria, they could complete another questionnaire on another day.

2.3. Body temperature rhythm

The body temperature of the participants was measured using a forehead thermometer (BTM Thermometer model 8877, Biotest Medical Corporation, Taichung City, Taiwan) every hour for a total of 24 hours to avoid interfering with the participants' sleep. To determine the phase value of the circadian rhythm, the time of the patient's lowest body temperature was compared with the temperature rhythm of healthy individuals, including morning- and evening-type.^{27–29} If the participant's minimum body temperature was outside the reference interval (from 3:00 to 7:00), their circadian rhythm was considered to be displaced or disturbed (Figure 1).

2.4. Objective sleep parameters

Participants were monitored using a portable polysomnography device (Embletta MPR with ST+ Proxy, Natus Medical, Pleasanton, CA, USA). It provided a continuous record for up to 12 hours. Data was recorded for a total of 24 hours starting at 21:00, and the record-

ing was interrupted twice to download the records. Recordings included electroencephalograph (EEG) (C4/A1, F4/A1, O2/A1), chin electromyograph (EMG), and electrooculography (EOG) (right and left). Sleep stage analysis was scored according to the American Academy of Sleep Medicine Scoring Manual version 2.1 by a certified sleep technologist (Y.-C. Lai and C.-C. Lin).

2.5. Statistical analysis

Variables are presented as the mean ± standard deviation (SD) and numbers with percentages (categorical variables). A t-test and chi-squared test were used for comparisons between groups. All statistical analyses were performed using PASW Statistics 18 (IBM, NY, USA) and all figures were drawn using MedCalc 19.6.3 (MedCalc Software Ltd, Ostend, Belgium). All analyses were performed as two-tailed tests, and *p* < 0.05 was considered to indicate a statistically significant difference.

3. Results

3.1. Self-reported sleep quality

To evaluate subjective sleep quality, a total of 30 questionnaires were completed by 8 elderly participants (mean age of 77.1 years) and 13 questionnaires were completed by 4 young participants (mean age 38.3 years) (Table 1). The total sleep score of the young group was notably lower than the elderly group (young vs. elderly, 39.2 vs. 52.9, *p* = 0.068). The average scores for sleep depth, sleep onset latency, number of awakenings, time spent awake, and overall sleep quality in the young group were 54.1, 27.1, 50.5, 26.4, and 38.2, respectively, while the average scores in the elderly group were 43.3, 54.3, 54.5, 52.9, and 52.4, respectively (Table 2 and Figure 2). Compared with the older participants, the young participants reported significantly lower scores for sleep onset latency (*p* = 0.004), and time spent awake (*p* = 0.01).

3.2. Body temperature rhythm

Next, we assessed the circadian rhythms of the patients in the RCC. There were 24 participants who had their body temperature measured, 19 of whom were elderly and 5 of whom were young; the mean ages were 81.2 and 54.6 years in the elderly and young groups, respectively (Table 1). Only 21.1% (elderly group) and 20.0% (young

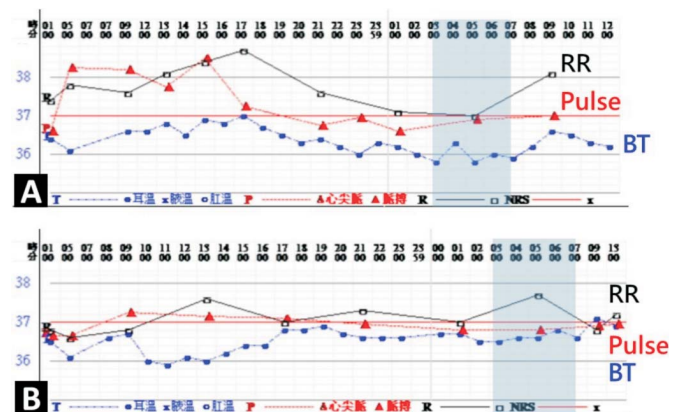


Figure 1. Examples of 24-hour body temperature (BT) rhythm. A) The nadir of BT during 3:00 to 7:00 shows normal temperature rhythm. B) The nadir of BT other than this period shows disrupted temperature rhythm. Blue circle line: body temperature (BT); red triangle line: pulse; black square line: respiratory rate (RR).

Table 1
Basic characteristics of the participants of each study.

Characteristic	RCSQ		24-hour BT		24-hour PSG
	Elder group (n = 8)	Young group (n = 4)	Elder group (n = 19)	Young group (n = 5)	Elderly (n = 6)
Age, year	77.1 ± 7.2	38.3 ± 16.1	81.2 ± 8.1	54.6 ± 6.7	79.2 ± 10.0
Gender, male:female	3:5	4:0	8:11	3:2	4:1
BMI, kg/m ²	23.0 ± 5.5	25.1 ± 8.9	23.4 ± 6.3	27.9 ± 9.7	24.7 ± 3.3
Duration of MV, day	38.8 ± 14.5	34.3 ± 3.9	28.6 ± 12.9	30.4 ± 14.6	48.2 ± 20.3
APACHE II Score	11.3 ± 2.0	7.3 ± 2.2	10.7 ± 2.7	7.4 ± 3.6	9.7 ± 2.8
Cause of respiratory failure*					
Pneumonia	4	2	7	1	3
Sepsis	3	0	5	1	1
COPD	1	0	1	0	4
Cardiac arrest	1	0	3	0	0
Pulmonary edema	4	1	9	1	5
Gastrointestinal bleeding	1	0	4	0	1
ARDS	1	1	0	0	0
Intracerebral hemorrhage	0	2	1	2	0
Trauma	0	1	0	0	1
Post-surgery	0	1	3	3	2
Tracheostomy	3 (37.5%)	1 (25%)	8 (42%)	1 (20%)	4 (66.7%)
Mode of MV					
CMV	0	0	9 (47.4%)	2 (40%)	1 (16.7%)
PSV	7 (87.5%)	1 (25%)	7 (36.8%)	3 (60%)	3 (50%)
CPAP	1 (12.5%)	1 (25%)	1 (5.3%)	0	1 (16.7%)
T-Piece	0	2 (50%)	2 (10.5%)	0	1 (16.7%)
Use of hypnotics	4 (50%)	1 (25%)	8 (42.1%)	1 (20%)	1 (16.7%)
Use of opioids	0	0	0	0	0

Data are presented as the mean ± standard deviation; number; or number (percentage).

* Cause of respiratory failure may be more than 1.

APACHE: acute physiology and chronic health evaluation; ARDS: acute respiratory distress syndrome; BMI: body mass index; BT: body temperature; CMV: control mechanical ventilation; COPD: chronic obstructive pulmonary disease; CPAP: continuous positive airway pressure; MV: mechanical ventilation; PSG: polysomnography; PSV: pressure support ventilation; RCSQ: Richards-Campbell Sleep Questionnaire.

Table 2
Results of the Richards-Campbell sleep questionnaire.

Questionnaire questions	Elder group (n = 8) (30 surveys)	Young group (n = 4) (13 surveys)	p
Q1. My sleep last night was: Deep sleep (100) / Light sleep (0)	43.3 ± 22.4	54.1 ± 28.7	0.192
Q2. Last night, the first time I got to sleep, I: Fell asleep almost immediately (100) / Just never could fall asleep (0)	54.3 ± 25.5	27.1 ± 30.1	0.004
Q3. Last night I was: Awake very little (100) / Awake all night long	54.5 ± 30.5	50.5 ± 27.7	0.682
Q4. Last night when I woke up or was awakened, I: Got back to sleep immediately (100) / Couldn't get back to sleep (0)	52.9 ± 29.6	26.4 ± 29.5	0.01
Q5. I would describe my sleep last night as: A good night's sleep (100) / A bad night's sleep (0)	59.4 ± 29.0	38.2 ± 36.9	0.048
Total sleep score (average of 5 items above)	52.9 ± 20.3	39.2 ± 25.5	0.068

Data are presented as the mean ± standard deviation.

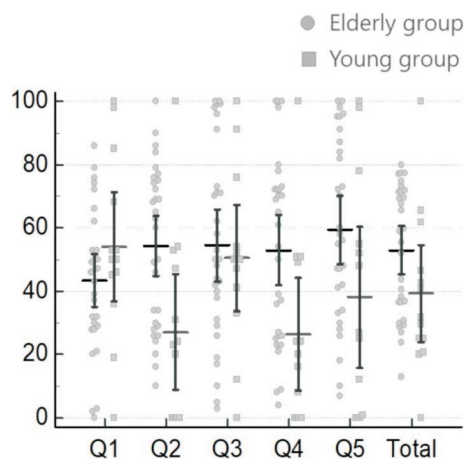


Figure 2. Results of the Richards-Campbell sleep questionnaire (RCSQ). The strip plot shows the distribution, mean and 95% confidence intervals for the RCSQ results. There are 5 questions in the questionnaire, including depth of sleep (Q1), sleep onset latency (Q2), number of awakenings (Q3), time spent awake (Q4), and overall sleep quality (Q5).

group) of the subjects had a normal body temperature rhythm, and the mean minimum deviation was 0.4 and -1.8 hours, respectively (Figure 3).

3.3. Objective sleep parameters

A total of 7 patients were assessed using a portable polysomnography device to understand their objective sleep parameters, how-

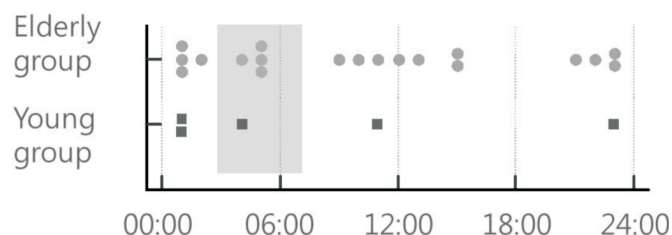


Figure 3. The distribution of the nadir of 24-hour body temperature in the two groups. The gray area (3:00–7:00) is the time during which the lowest body temperature occurs in the general healthy population.

ever only 6 of them completed the 24-hour PSG study (one failed due to the EEG leads detaching). Their mean age was 79.2 years (Table 1). The mean recording time was 1370.7 ± 46.5 minutes (22.85 ± 0.78 hours). The total sleep time (TST) was 411.1 ± 247.6 minutes (6.85 ± 4.13 hours), and the split between stage N1, N2, N3 and REM was 23.1%, 70.1%, 3.3% and 3.5% of total sleep, respectively. The arousal index was 13.6 ± 1.9 times per hour. In the nighttime, the total sleep time was 178.5 ± 139.7 and the sleep efficiency was 33.7 ± 26.9%. The majority of sleep (61.5 ± 14.5% of total sleep) occurred intermittently during the daytime (Table 3 and Figure 4).

4. Discussion

Among the patients who were treated with PMV in the RCC, our study demonstrated that: (1) the average RCSQ total sleep score of elderly patients was only 52.9; (2) only 21.1% of elderly patients had normal body temperature circadian rhythm; (3) although the mean total sleep time of the elderly patients was 411.1 minutes (6.85 hours), the sleep architecture was disrupted, most sleep was light sleep, and the majority (61.5%) of sleep occurred intermittently during the daytime. Taken together, these results indicate that our patients' subjective sleep quality, circadian rhythms, and objective sleep conditions were all seriously negatively impacted.

RCSQ is a reliable, valid, and widely used sleep questionnaire which can evaluate subjective sleep quality in the ICU.^{26,30} The total sleep score was correlated with the sleep efficiency index as determined by PSG (r = 0.58). Our study shows that the total sleep score of the elderly was 52.9, which is similar to previous studies measuring RCSQ in the ICU, where scores ranged from 43.6 to 60.2.^{26,31-33} The distribution of this score was wide in our study, just as in previous studies, which reflects the variation in subjective perception for the quality of sleep.

The circadian and homeostatic systems are the two major systems which regulate sleep/wake cycles, and disruption of the circadian rhythm is usually related to sleep disturbance.³⁴ As melatonin, cortisol, and core body temperature have a circadian pattern, they can all be used to measure the rhythm of ICU patients. Although a forehead thermometer cannot accurately measure the core temperature, with underestimated by 0.5 °C, it's considered a reasonable substitute for the core body temperature rhythm.³⁵ Our study found that only 21.1% of elderly and 20.0% of young PMV patients had a normal body temperature rhythm. These results are similar to

a previous study conducted in the ICU (19% had the nadir temperature within the reference period).³⁶

It is not easy to measure a patients' sleep in an ICU or SWU. PSG remains the gold standard for objective sleep monitoring, however it is expensive, labor-consuming, and difficult to use as a daily practice in ICU or SWU patients. It is also difficult to score the sleep electroencephalograph (EEG) due to atypical sleep and pathological wakefulness which can occur in patients with critical illness.³⁷ Actigraphy or direct observation is simple but tends to overestimate sleep time and efficiency.^{30,38} The bispectral index (BIS) can be used as an alternative method for sleep monitoring, but its accuracy in an ICU setting remains unclear.^{39,40} Compared with the sleep status of age-matched healthy subjects in the literature, our results showed that the TST of elderly PMV patients was 411.1 minutes (6.85 hours) which was not significantly different than the healthy patients.¹⁴ However, 61.5% of their sleep occurred during the day. If PSG was only performed at night, the total sleep time of these patients would be underestimated. In previous studies, the proportion of daytime sleep in the ICU ranged from 32.2 to 57%, while in an SWU study it was 61.8%.^{17-21,24} The difference in these results may be due to the age of the patients or the length of the ICU stay. Furthermore, the deep sleep of these patients was markedly decreased while the sleep efficacy was also significantly decreased. In previous studies conducted in the ICU or SWU, N3, REM sleep and sleep efficacy were 0.29-28%, 3.3-14.3%, and 38-71%, respectively.^{17-19,21,22,24,25} Our data similarly showed that N3 (3.3%), REM (3.5%) and sleep efficacy (33.7%) were significantly decreased. Again, these results could indicate the more fragile sleep nature of elderly adults.

A strength of the current study is that it is the first study to evaluate the sleep quality and quantity of elderly PMV patients in the SWU by using 24-hour PSG. There were three stages used to broadly evaluate the patient's subjective sleep quality, their circadian rhythm, and their objective sleep quality. It should however be noted that there are some limitations to the present study. Its single center study design and the small number of enrolled patients may lead to sampling errors. The patients were assessed separately in the three stages of this study, meaning that the results cannot be assessed in parallel. We cannot control or analyze the impact of nursing activities (e.g., changing body positions, percussion, feeding, bathing), and the external environment (e.g., noise) on these patients. Nevertheless, it still provides a more comprehensive view of the sleep quality of the elderly receiving PMV.

Table 3
The results of 24-hour polysomnography.

	Nighttime	Daytime	24-hour
Recording time, minutes	534.9 ± 12.2	835.9 ± 47.7	1370.7 ± 46.5
Sleeping time, minutes	178.5 ± 139.7	232.6 ± 114.9	411.1 ± 247.6
Sleep efficiency, %	33.7 ± 26.9	28.0 ± 14.2	30.2 ± 18.6
Sleep latency, minutes	27.3 ± 15.9		
Stage N1, minutes	36.4 ± 25.0	56.3 ± 30.3	92.7 ± 49.9
Stage N1, %	24.8 ± 8.8	24.0 ± 5.6	23.1 ± 3.6
Stage N2, minutes	117.8 ± 90.5	157.1 ± 60.3	274.9 ± 143.3
Stage N2, %	67.7 ± 8.6	70.4 ± 8.9	70.1 ± 8.2
Stage N3, minutes	16.1 ± 37.5	4.9 ± 7.3	21.0 ± 39.6
Stage N3, %	5.2 ± 11.8	1.5 ± 1.8	3.3 ± 6.0
Stage REM, minutes	8.2 ± 12.8	14.3 ± 21.6	22.5 ± 34.1
Stage REM, %	2.4 ± 3.7	4.1 ± 5.3	3.5 ± 4.5
Arousals index, No. per hour	13.0 ± 5.5	14.0 ± 2.6	13.6 ± 1.9
Sleeping in daytime, %			61.5 ± 14.5

Data are presented as the mean ± standard deviation.
N: Non-REM sleep; No.: number; REM: rapid eye movement; Nighttime: 21:00-06:00, light-off time; daytime: 06:00-21:00, light-on time.

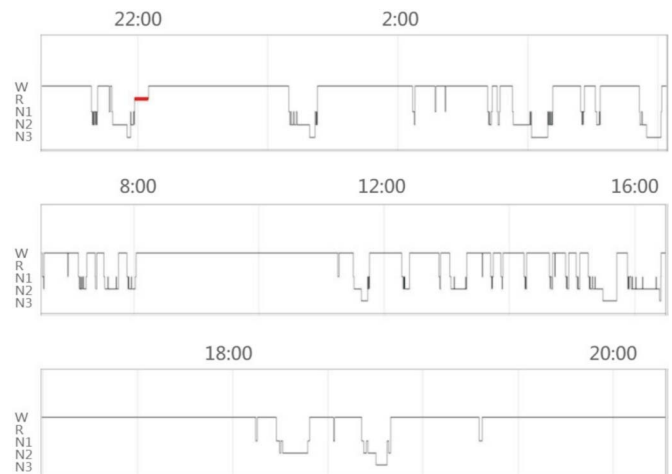


Figure 4. Example of a 24-hour hypnograms scored by 24-hour PSG from one participant. The vertical axis is in descending order: sleep-stage of wake (W), REM (R), and NREM stages 1, 2, and 3 (N1, N2, N3).

5. Conclusion

In this three-stage observational study of the elderly being treated with PMV, the RCSQ questionnaire revealed poor subjective sleep quality, the 24-hour body temperature measurement demonstrated disrupted circadian rhythms, and the 24-hour PSG confirmed disturbed and fragmented sleep. This study provides a more comprehensive view of sleep in the elderly with PMV.

Author contributions

Conceptualization, C.-H. Chen, H.-P. Chung and K.-C. Kuo; methodology, C.-H. Chen, H.-P. Chung and C.-L. Liu; data curation, Y.-C. Lai, C.-C. Lin, and M.-C. Pai; formal analysis, C.-H. Chen., K.-C. Kuo and C.-Y. Lin; writing — original draft preparation, C.-H. Chen.; writing — review and editing, C.-L. Liu; supervision, C.-Yi. Lin; all authors have read and agreed to the published version of the manuscript.

The material contained in the manuscript has not been previously published and is not being concurrently submitted elsewhere.

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