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Romanian Journal of Anaesthesia and Intensive Care 2018 Vol 25 No 1, 61-72

REVIEW ARTICLE

DOI: http://dx.doi.org/10.21454/rjaic.7518.251.ven

The effects of mechanical ventilation on the quality of sleep of hospitalised patients in the Intensive Care Unit

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Abstract

Aim: To examine the effects of mechanical ventilation on the quality of sleep in patients in the intensive care unit (ICU) using recent and relevant literature.

Methods: To verify the examined objective, the results of the analysis of available original scientific works have been used including defined inclusion/exclusion criteria and search strategy. Appropriate works found were analysed further. The applied methodology was in line with the general principles of Evidence-Based Medicine. The following literary databases were used: CINAHL, Medline and gray literature: Google Scholar.

Results: A total of 91 trials were found. Eleven of these relevant to the follow-up analysis were selected: all trials were carried out under real ICU conditions and the total of 192 patients were included in the review. There is an agreement within all trials that sleep in patients requiring mechanical ventilation is disturbed. Most reviewed trials have shown that mechanical ventilation is probably not the main factor causing sleep disturbances, but an appropriate ventilation strategy can significantly help to improve its quality by reducing the frequency of the patient-ventilator asynchrony.

Conclusion: Based on the analysis, it appears that an appropriate ventilation mode setting can have a beneficial effect on the quality of sleep in ICU patients.

Keywords: mechanical ventilation, quality of sleep, intensive care unit

Received: 12 March 2018 / Accepted: 28 March 2018 **Rom J Anaesth Intensive Care 2018; 25: 61-72**

Introduction

Sleep is one of the basic physiological needs. A greater number of trials that focused on sleep disorders of patients at intensive care units (ICU) has been elaborated in the last decade. There is increasingly more evidence that sleep deprivation is connected with a general alteration of the condition with negative biological effects on the organism. Sleep disorder in critically ill patients is connected with a higher incidence of delirium [1], a higher risk of non-invasive ventilation failure [2], has an effect on the neuropsychological effects of survivors as part of the post-intensive care syndrome (e.g. cognitive deficiencies, anxiety, post-traumatic stress disorder) [3]. Other epidemiological trials show that sleep disorders in critically ill patients have serious consequences at the level of individual cardio-respiratory systems [4], affect metabolic, endocrine and immune responses [5, 6], participate in prolonged wound healing [7] and increase the frequency of falls [8]. These consequences lead to prolonged hospitalisation [1], increased mortality [9-11] and deterioration in quality of life [12].

Sleep disorders are very common in patients in an ICU [13]. The gold standard for assessing sleep architecture is the polysomnography method [14]. They confirm the existence of changes not only in terms of quantity but also in terms of quality. The sleep of ICU patients with altered consciousness is fragmented and

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its architecture is disrupted [10, 13, 15, 16]. There is a growing number of trials that indicate that the standard brain electrical activity monitoring evaluation, which is currently valid and recommended [17], is not reliable in critically ill patients [15, 18, 19]. The reliability of standard evaluation in the general population is relatively high, the kappa coefficient (κ) is in the range of 0.68-0.82, while in the group of critically ill patients this coefficient is significantly lower 0.19 [20]. According to Drouot et al. [21] the cause of this significant variability are neurobiological changes that are involved in the sleep pattern abnormalities in critical conditions. The first trial that provided relevant evidence of these changes was the trial by Cooper et al. [15]. In line with this finding, the authors further developed additional criteria to increase the sensitivity of sleep architecture evaluations in critical conditions [18, 19].

The ICU environment is very inhospitable and there are many factors that negatively effect the quality of sleep in critical ill patients. The most cited factors include noise, light, nursing interventions, underlying disease and physical condition of the patient, pain and discomfort, psychosocial factors, medication and mechanical ventilation [10, 22, 23]. In order to achieve and maintain a maximum level of sleep quality, it is necessary to implement organisational interventions – sleep promoting strategies [24-27]. At present, some attention is directed to the effects and importance of mechanical ventilation on the quality of sleep [28, 29]. A trial by Estebana et al. [30] indicates that 40% of patients hospitalised at ICU require mechanical ventilation, although its exact effect on sleep architecture is uncertain. Based on available recent and relevant literary sources, we examine the effects of mechanical ventilation on the quality of sleep in patients in intensive care units. We assume that sleep in ventilated patients is significantly impaired and a mode of ventilation effect on sleep quality will be confirmed.

Material and methods

To verify the aim (the effects of mechanical ventilation on the quality of sleep in patients in ICU) the results of the analysis of available original scientific works were used. Defined inclusion/exclusion criteria and search strategy were used. Appropriate works were analysed further. The applied methodology was in line with the general principles of Evidence-Based Medicine [31].

The inclusion and exclusion criteria

Based on the research aim, the following inclusion and exclusion criteria were established: time range of 2000-2017 (older trials were found to be outdated), the availability of the *full text* of the article in English, original trials in peer-reviewed journals. Exclusion criteria: availability of abstracts only, articles published outside the specified time period and survey studies.

Sources and search strategy

When searching for relevant sources, these electronic databases were used: CINAHL, Medline and gray literature: Google Scholar. The following keywords were used for search: intensive care unit, mechanical ventilation, quality of sleep. In the initial phase of the search, the primary key words were extended by synonyms and analogical terms connected by *Boolean* operators, AND and OR. The same search criteria were used for each database.

Results

A total of 91 trials were found in selected databases. Based on the primary analysis, works not relevant for the specified area of interest and works which did not meet the inclusion criteria (or met the exclusion criteria) were excluded. A total of 11 works were included in the analysis and in the review – all of them were conducted in real ICU conditions. The process of selection of the trials is shown in Figure 1, as recommended by PRISMA (Figure 1). The analysed trials, methods and results are summarised in Table 1.

In the case of the analysed trials where all research investigated the influence of mechanical ventilation on the quality and quantity of sleep, there was a significant variability and focus in the design of the trials. The groups included small numbers of patients (11-24) hospitalised in ICUs (either general or specialised) in tertiary (university) hospitals. A total of 192 patients were included in the review. The results obtained allow a rough and merely indicative comparison of the influence of artificial ventilation on the quality of sleep across the individual works. Due to their different characteristics, methodological inconsistencies, the examined works were not systematically analysed according to the recommended and accepted methodology [32]. Significant differences in the design of the evaluation of the sleep quality in individual trials do not allow for a full comparative systematic statistical meta-analysis.

Despite the significant variability of the evaluated trials, it can be inferred from the comparison of the results obtained that there is an agreement among the trials that the disrupted sleep architecture of patients with mechanical ventilation is confirmed. Finding the right mode and setting can affect the quality of sleep through various mechanisms. Although the trials demonstrate that mechanical ventilation is apparently not the main factor causing sleep disruptions, an appropriate ventilation strategy in a specific group of patients can significantly help to improve the quality of sleep.

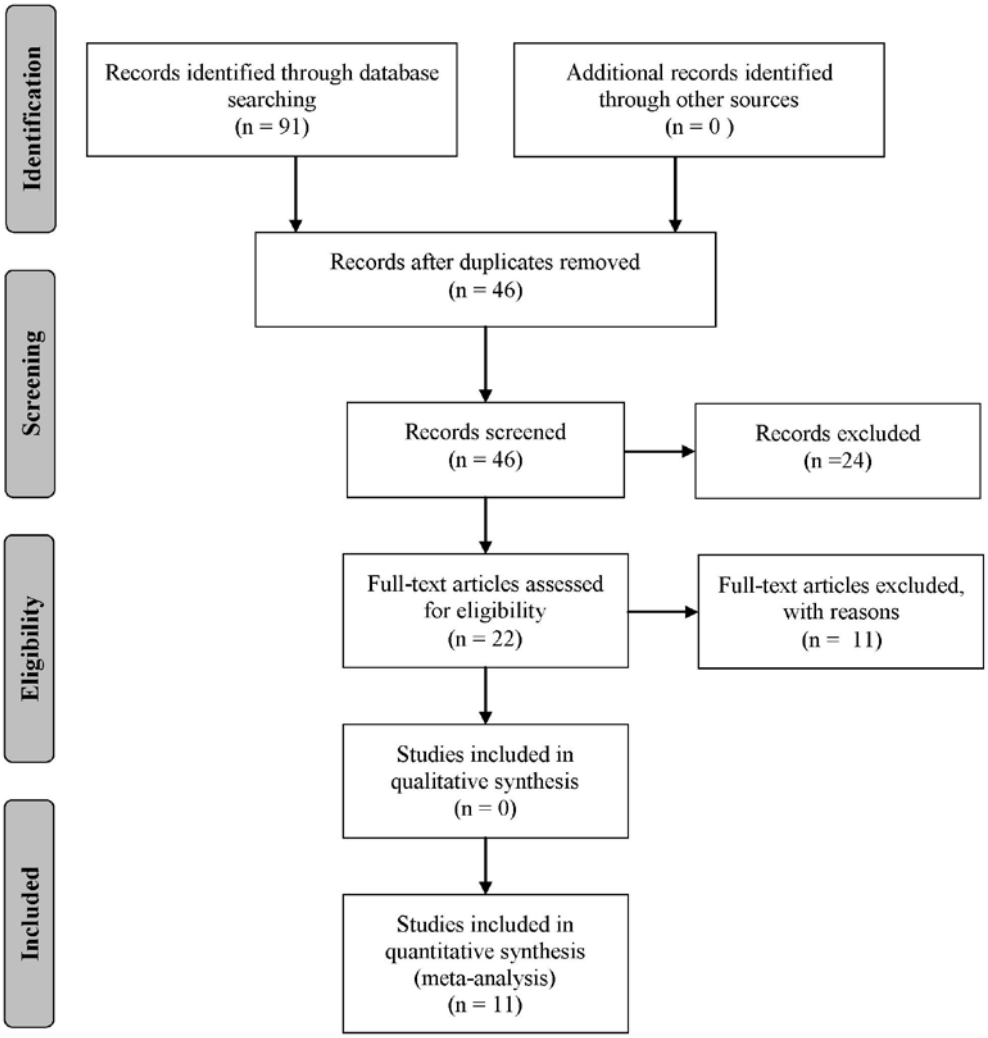

Fig. 1. The process of study selection (a PRISMA flow diagram)

Parthasarathy and Tobin [33] evaluated 11 ventilated patients with three modes: ACV (assist control ventilation), PSV (pressure support ventilation), PSV + dead space and its effects on sleep architecture. They confirmed that the ventilation mode and its setting affect quality of sleep. PSV mode is significantly connected with the increase in sleep fragmentation (arousal + awakening / h): [PSV: 79 ± 7 cf. ACV 54 ± 7, $p = 0.02$], central apnea (6 patients), and apnea in PSV is connected with higher frequency of awakenings [$r = 0.66$; $p = 0.01$], which may impair the quality of sleep. The authors confirmed that adding dead space in this group of patients (6) resulted in a significant reduction in sleep fragmentation [83 ± 12 cf. 44 ± 6, $p < 0.01$]. French randomised crossover trial by Toublanc et al. [34] carried out a comparative evaluation of the impact of ACV and low PSV (6 cm H_20) on the quality of sleep in 20 ventilated patients with acute respiratory failure. The results of the trial confirm that ACV is significantly connected ($p < 0.05$) with better quality of sleep than low PSV. The trial presents the conclusions that the ACV mode during the first part of the night (22:00 - 02:00) is connected with a significant decrease in the number of awakenings [30.8 ± 28.2% cf. 69.0 ± 26.2, $p < 0.05$] connected with an increase in N1 [34.8 ± 18.6% cf. 17.1 cf. 15%, $p < 0.05$] and N2 [33.0 ± 24.6% cf. 11.4 ± 15.9%, $p < 0.05$) and a significant increase in N3 [6.3 ± 7.7% cf. 0.3 ± 1.0%, $p < 0.01$] and N4 [5.4 ± 13.2% cf. 0.0 ± 0.0%, $p < 0.01$] during the second part of the night (02:00-06.00). A French prospective trial by Cabello et al. [35] compared ACV mode with cPSV (clinically adjusted pressure support ventilation) mode and aPSV (automatically adjusted pressure support ventilation) in 15 ventilated patients. They based their research on the hypothesis that adjusting the level of support in accordance with the patient's need and effort will affect the sleep fragmentation. The results of this trial demonstrated that no statistically significant changes in sleep architecture were confirmed among the ACV,

Table 1. Characteristics of trials focused on the effects of the mechanical ventilationand its impact on the sleep architecture in the intensive care units

Author (year), Country	Design	n	PSG record	Ventilation mode	PSG results	Another effect	Conclusion
Parthasarathy, Tobin (2002), USA	Randomised crossover clinical trial	11	22:00 – 06:00	ACV (2 h)	↓ sleep fragmentation (54 ± 7 / h) TST: 90 ± 6 min SE (%): 75 ± 5	Occurrence of apnea: 0 patients	PSV causes an increase in sleep fragmentation (number of arousals + awakenings / h): [79 ± 7 cf. ACV 54 ± 7, p = 0.02], significantly lower sleep efficiency (SE): [63 ± 5% cf. 75 ± 5%, p < 0.05]. PSV is associated with a more frequent central apnea (6 patients). In patients with apnea, adding dead space significantly reduces sleep fragmentation [44 ± 6 cf. 83 ± 12, p = 0.02]. The apnea in PSV is associated with a more frequent awakenings [r = 0.66; p = 0.01], which may impair the quality of sleep. *Effects of the ventilation mode and its setting on the sleep architecture confirmed. ACV is connected with better quality of sleep than PSV.*
				PSV (2 h)	TST: 75 ± 6 min ↑ sleep fragmentation (79 ± 7 / h) SE (%): 63 ± 5	Occurrence of apnea: 6 patients	
				PSV + ↑ dead space (2 h)	TST: 82 ± 7 min SE (%): 81 ± 7		
Toublanc et al. (2007), France	Randomised crossover clinical trial	20	22:00 – 06:00	ACV (4 h)	*The first part of the night* ↑ N1 (34.8 ± 18.6%) ↑ N2 (33 ± 24.6%) N3, N4 and REM without distinction, ↓ number of arousals (30.8 ± 28.2%) *The second part of the night* N1, N2 and REM without distinction, number of arousals ↑ N3 (6.3 ± 7.7%) ↑ N4 (5.4 ± 13.2%)		ACV is connected with better quality of sleep during the first part of the night N1 [34.8 ± 18.6% cf. 17.1 ± 15%, p < 0.05], N2 [33.0 ± 24.6% cf. 11.4 ± 15.9%, p < 0.05], and a decrease in the number of awakenings [30.8 ± 28.2% cf. 69.0 ± 26.2%, p < 0.05] and is connected with a significant increase in N3 [6.3 ± 7.7% cf. 0.3 ± 1.0%, p < 0.01] and N4 [5.4 ± 13.2% cf. 0.0 ± 0.0%, p < 0.05] during the second part of the night. *ACV is connected with better quality of sleep than low PSV.*
				Low PSV - 6 cm H_20 (4 h)	*The first part of the night* ↓ N1 (17.1 ± 15%) ↓ N2 (11.4 ± 15.9%) ↑ number of arousals (69 ± 26.2%) without difference in N3, N4 and REM *The second part of the night* N1, N2 and REM without distinction number of arousals ↓ N3 (0.3 ± 1%) absence of N4		
Cabello et al. (2008), France	Comparative crossover clinical trial	15	6 h	ACV (6 h)	REM: 7% (0-13) Sleep fragmentation: 30 (17-41) SE: 58% (44-82) SWS 37 min: (4-62) N1: 8% (1-15) N2: 54% (47-79)	Occurrence of apnea: 0 / h Ineffective effort: 7 ± 18 / h Arousal, noise-related awakening: 4 ± 4 / h	No significant difference in the sleep architecture has been confirmed regarding the individual ventilation modes: ACV cf. cPSV cf. aPSV: N1 [8% cf. 7% cf. 5%, p = 0.62], N2 [54% cf. 67% cf. 39%, p = 0.32], SWS [37 min cf. 26 min cf. 24 min, p = 0.79], REM [7% cf. 4% cf. 1%, p = 0.54], sleep fragmentation [30 cf. 28 cf. 23, p = 0.62] a sleep efficiency [58% cf. 44% cf. 63%, p = 0.15].
				cPSV (6 h)	REM: 4%: (0-10) Sleep fragmentation: 28 (17-53)	Occurrence of apnea:	

					SE: 44% (29-80) SWS 26 min (0-68) N1: 7% (1-23) N2: 67% (54-84)	5 ± 6 / h Ineffective effort: 12 ± 23 / h Arousal, noise-related awakening: 5 ± 6 / h	As for the individual ventilation modes, no significant difference in relation to the noise-related sleep fragmentation has been confirmed [ACV 4 ± 4 cf. cPSV 5 ± 6 cf. aPSV 6 ± 7, p = 0.55]. *The trial confirmed a change in sleep architecture in ventilated patients, but the ventilation mode does not have a key impact on the change of the architecture.*
				aPSV (6 h)	REM: 1% (0-7) Sleep fragmentation: 23 (21-45) SE: 63% (29-80) SWS: 24 min (0-51) N1: 5% (0-11) N2: 39% (52-62)	Occurrence of apnea: 7 ± 11 / h Ineffective effort: 16 ± 45 / h Arousal, noise-related awakening: 6 ± 7 / h	
Andréjak et al. (2013), France	Randomised crossover clinical trial	26	22:00 – 06:00	PCV (4 h)	↓ N1: 14% (15 ± 14) ↑ N2: 33% (35 ± 23) ↑ SWS: 6.55% (8.9 ± 10.0) ↑ REM: 6.5% (3.46 ± 6.0) ↑ SE: 63% (61 ± 25)		PCV is significantly connected with improved quality of sleep in the monitored parameters compared to low PSV: SE [63% cf. 37%, p = 0.0002], N2 [33% cf. 13%, p = 0.0005], SWS [9% cf. 3.5%, p = 0.003], and REM [6.5% cf. 0%, p = 0.003]. *PCV is associated with better quality of sleep than low PSV.*
				Low - PSV - 6 cm H_20 (4 h)	↑ N1: 16% (15 ± 10) ↓ N2: 13% (20 ± 21) ↓ SWS: 0% (3.5 ± 9) ↓ REM: 0% (0.7 ± 2) ↓ SE: 37% (39 ± 29)		
Bosma et al. (2007), Italy	Randomised crossover clinical trial	13	22:00 – 08:00	PAV (1 night)	↑ TST: 334 ± 124 min ↓ Arousal: 9 / h (1-41) Number of arousals: 3.5 / h (0-24) ↑ SWS: 3% (0-16) ↑ REM: 9% (0-31)	Patient-ventilator asynchrony: 24 ± 15 / h Noise > 75 dB: 883 ± 275 Noise-related arousal: 2 (0-17 / h)	PAV in comparison with PSV is connected with better quality of sleep in selected indicators: arousal [9 (1–41) cf. 16 (2-74), p = 0.02], number of awakenings [3.5 (0-24) cf. 5.5 (1-24), p < 0.05], REM [9% (0-31) cf. 4% (0-23), p < 0.05] a SWS [3% (0-16) cf. 1% (0-10), p < 0.05]. Patient-ventilator asynchrony was significantly lower in PAV (24 ± 15) than in PSV (53 ± 59), p = 0.02 and it significantly correlated with the number of arousals / h (R^2 = 0.65, p = 0.0001). Noise has no significant effect on the number of arousals. *PAV is in comparison with PSV connected with better quality of sleep.*
				PSV (1 night)	↓ TST: 314 ± 140 min ↑ Arousal: 16 / h (2-74) ↑ Number of arousals: 5.5 / h (1-24) ↓ SWS: 1% (0-10) ↓ REM: 4% (0-23)	Patient-ventilator asynchrony: 53 ± 59 / h Noise > 75 dB: 942 ± 293 Noise-related arousal: 2 (0-16 / h)	
Alexopoulou et al. (2013), Greece	Randomised crossover clinical trial	14	24 hours 07:00 – 23:00 23.00-7.00	PAV + [load adjustable gain factors] (3 x 4 hours)	↓ N1: 59.7%: (16.9-96.2) ↑ N2 31.1%: (0.7-73.2) SWS 0% (0-2.5) ↓ REM 0% (0-8.4) ↑ Sleep fragmentation 18.8: (13.1-33.1)	Patient-ventilator asynchrony: 5.1 (1.1-17.1 / h)	In PAV + mode, there is a statistically significant reduction in asynchrony[PAV + 5.1 (1.1-17.1 / h) cf. PSV 43.0 (3.8-442.5 / h), p = 0.019] without a statistically significant impact on the change in sleep architecture. PAV + cf. PSV: N1 [59.7% (16.9 ± 96.2) cf. 63.7 % (12.4 ± 97.6), p = 0.754], N2 [31.1% (0.7 ± 73.2) cf. 5.0% (0.0 ± 65.8), p = 0.182], SWS [0.0% (0.0 ± 2.5) cf. 0.0 (0.0–1.9), p = 0.600], REM [0.0% (0.0 ± 8.4) cf. 5.8% (0.0 ± 21.9), p = 0.021]. *Although the PAV + mode is connected with improved patient-ventilator synchronisation, no significant role of synchronisation*
				PSV (3 x 4 hours)	↑ N1: 63.7%: (12.4-97.6) ↓ N2: 5.0% (0-65.8) SWS: 0% (0.0-1.9)	Patient-ventilator asynchrony: 43.0 (3.8-442.5 / h)	

					↑ REM 5.8% (0.0-21.9) ↓ Sleep fragmentation: 18.1 (7.0-22.8)		*in the quality of sleep has been confirmed.*
Alexopoulo et al. (2007), Greece	Randomised crossover clinical trial	17	21.00-7.00	Protocol A Sedation (21:00 – 07:00) PAV + / PSV (2 levels of assistance)	SE %: PAV + 98.9 ± 2.3 cf. 87.7 ± 16.4 ($p < 0.05$) other sleep parameters without statistical significance (not specified in more detail).		*There was no significant difference between ventilation modes (PAV + PSV) and specific setting in relation to the sleep architecture in monitored parameters.*
			23:00 – 06:00	Protocol B Without sedation (23:00 – 06:00) PAV + / PSV (2 levels of assistance)	There was no statistically significant difference between setting and mode in the quality of sleep in the evaluated parameters (not specified in more detail).		
Delisle et al. (2011), Canada	Comparative crossover clinical trial	14	24 hod (4 h)	NAVA (2 x 4 hours)	↓ N1: 4% (3-5) ↓ N2: 55% (52-58) ↑ SWS 20.5% (16-25) ↑ REM 16.5% (13-29) ↓ Sleep fragmentation 17.5 (8-21.5) ↑ SE 73.5% (52.5-77)	Occurrence of apnea: 0 / h Ineffective effort: 0 / h Noise-related arousal: 6 ± 3.5 / h	NAVA showed statistically more significant differences in the evaluated sleep parameters than PSV: SWS [20.5% (16-25) cf. 16.5% (17-20), p = 0.001], REM 16.5% (13-29) cf. 4.5% (3-11), p = 0.001], sleep fragmentation [17.5 (8-21.5) cf. 33.5 (25-54), p = 0.001], sleep efficiency: [73.5% (52.5-77) cf. 44% (29-73.5), p = 0.001]. Also, this intelligent mode is associated with a significant reduction in apnea [NAVA 0 / h cf. PSV 10.5 ± 11 / h, p = 0.005] and ineffective patient effort [NAVA 0 / h cf. PSV 24 ± 23 / h, p = 0.001). No significant difference in relation to the noise-related arousal has been confirmed regarding the individual ventilation modes [NAVA 6 ± 3.5 cf. PSV 7.5 ± 3, p = 0.19]. *NAVA is connected with better quality of sleep than PSV.*
				PSV (2 x 4 hours)	↑ N1 7.5% (4-15) ↑ N2 68% (66-75) ↓ SWS 16.5% (17-20) ↓ REM 4.5% (3-11) ↑ Sleep fragmentation 33.5 (25-54) ↓ SE 44% (29-73.5)	Occurrence of apnea: 10.5 ± 11 / h Ineffective effort: 24 ± 23 / h Noise-related arousal: 7.5 ± 3 / h	
Roche Campo et al. (2013), France	Randomised crossover clinical trial	16	22:00 – 08:00	Non – invasive ventilation (NIV): 5 h	↑ TST: 183 (133-211 min) ↑ SE: 61% (38-74) N1 + N2: 67% (56-75) ↑ SWS: 27% (13-35) ↑ REM: 9% (4-14) Sleep fragmentation: 25 (18-43)		Artificial ventilation of sleep in patients with tracheotomy on weaning has a positive effect on the selected indicators of the quality of sleep. TST [183 min (133-211) cf. 132 (28-192), p = 0.04], sleep efficiency [44% (9-63) cf. 61% (38-74), p = 0.04]. The other parameters were not significantly different in N1 and N2 [67% cf. 68%, p = 0.36], SWS [27% cf. 16%, p = 0.57], sleep fragmentation [25 cf. 23, p = 0.65]. *Connecting a patient in the first days of weaning to the UPV at night can reduce the patient's effort and improve the quality of sleep.*
				Spontaneous breathing (SB): 5 h	↓ TST: 132 (28-192 min) ↓ SE: 44% (9-63) N1 + N2: 68% (54-82) ↓ SWS: 16% (1-31) ↓ REM: 2% (0-5) Sleep fragmentation: 23 (12-36)		
Fanfulla et al. (2011), Italy	Descriptive study	22	24 h	11 NIV	↓ TST: 613 ± 249 min ↓ SWS: 23.8 ± 13.8% ↑ N1: 14.4 ± 10.5% ↑ N2: 50.9 ± 12.3% ↓ REM: 10.8 ± 7.4%	Ineffective effort: 45.3 ± 66 / h Patient-ventilator asynchrony: 3.4 ± 4.9/h	Ventilation mode does not have a key impact on sleep architecture and its quality, and noise has no significant impact on sleep fragmentation.

						Noise-related arousal: 3.6 ± 5.9 / h	*No significant changes in sleep architecture between spontaneous breathing and mechanical ventilation have been confirmed.*
				11 SB	↑ TST: 645 ± 326 min ↑ SWS 31.9 ± 15.0 % ↓ N1: 13.1 ± 12.8% ↓ N2: 40.9 ± 13.5% ↑ REM (%) 14.2 ± 8.7	Noise-related arousal: 2.9 ± 3.8 / h	
Córdoba - Izquierdo et al. (2013), France	Randomised crossover clinical trial	24	16:00 – 09:00	conventional ventilator : NIV	↓ sleep fragmentation 14% (7.0-22.0) SE: 54% (48-61) N1: 8.3% (3.3-17) N2: 36% (28-51) SWS: 33% (21-50) REM: 10 (3.7-20)	Patient-ventilator asynchrony: 34 (15-7 / h) Ineffective effort: 2 (0-13 / h) Respiratory volume: 5.8 (5.1-6.8 ml/kg) Arousal, noise-related awakening: 8.7% [4.7-12] Noise peak: 98 / h [89-121]	It was confirmed that there was a significant reduction in patient-ventilator asynchrony when using the conventional ventilator [34 (15-76) cf. 174 (43-279), p = 0.02] and a less frequent ineffective effort [2 (0-13 / h) cf. 34 (15-125), p = 0.04], this has a positive impact on the reduction of sleep fragmentation [14% (7.0-22) cf. 28% (17-44), p = 0.02], other parameters are not significantly influenced by this effect: N1 [8.3% cf. 4.4%, p = 0.30], N2 [36% cf. 34%, p = 0.82], SWS [33% cf. 38%, p = 0.69], REM [10% cf. 15%, p = 0.91]. The conventional ventilator is associated with a significantly more frequent noise peak of98 / h [89-121] cf. 39 / h [21-69] p <0.01, which is connected with a significantly more frequent noise-related sleep fragmentation: 8.7% [4.7-12] cf. 1.8% [1.2-4.6] p = 0.001. *Type of ventilator (conventional cf. dedicated) has no significant impact on sleep architecture during NIV*
				Dedicated ventilator for NIV	↑ sleep fragmentation 28% (17-44) SE: 59% (46-74) N1: 4.4% (3-8) N2: 34% (24-54) SWS: 38% (5-45) REM: 15 (2.7-21)	Patient-ventilator asynchrony: 174 (43-279 / h) Ineffective effort: 34 (15-125 / h) Respiratory volume: 7.2 (6.7-8.8 ml/kg) Arousal, noise-related awakening: 1.8% [1.2-4.6] Noise peak: 39 / h [21-69]	

ACV: assist control ventilation, TST: total sleep time, SWS: slow wave sleep, PSV:pressure support ventilation, PAV: proportional assist ventilation, SE: sleep efficiency, cPSV: clinically adjusted pressure support ventilation, aPSV: automatically adjusted pressure support ventilation, NAVA: neurally adjusted ventilatory assist, SB: spontaneus breathing, NIV: non-invasive ventilation, REM: rapid eye movement, N1, N2, SWS- stage of sleep

cPSV and aPSV ventilation modes: N1 [8% cf. 7% cf. 5%, p = 0.62], N2 [54% cf. 67% cf. 39%, p = 0.32], SWS [37 min cf. 26 min cf. 24 min, p = 0.79], REM [7% cf. 4% cf. 1%, p = 0.54], sleep efficiency (SE) [58% cf. 44% cf. 63%, p = 0.15], sleep fragmentation [30 cf. 28 cf. 23, p = 0.62]. Andréjak et al. [36] evaluated in a crossover trial the effect of PCV (pressure-controlled ventilation) and low PSV (6 cm H_20) on the quality of sleep in 26 patients with severe COPD (chronic obstructive pulmonary disease). His primary goal was to achieve a night rest for breathing muscles, thus reducing respiratory effort and improving sleep architecture. The trial demonstrates that PCV patients have a significantly improved sleep efficiency (SE) [63% cf. 37%, p = 0.0002], an increased proportion of N2 [33% cf. 13%, p = 0.0005], SWS [9% cf. 3.5%, p = 0.003], and REM [6.5% cf. 0% p = 0.003]. In order to approximate the physiological respiratory patterns as much as possible and minimise the effects of artificial ventilation, new ventilation modes (PAV – proportional assist ventilation, NAVA – neutrally adjusted ventilatory assist) adapted to the patient's respiratory effort while preserving its variability have been implemented in recent years. Their goal is to achieve maximum patient-ventilator synchronisation. A number of research works demonstrate [37, 38] that asynchrony between patient and ventilator is common and is connected with increased mortality and extended ventilation period, and increases the likelihood of respiratory muscles injury. These trials aimed to provide relevant evidence of whether these new ventilation modes (NAVA, PAV) may affect the quality of sleep by achieving maximum synchronisation or not. A randomised Italian trial by Bosma et al. [39] compared in 13 patients PSV (1 night) and PAV (1 night). The trial confirms a significant improvement in the quality of sleep in PAV mode in several parameters: a significant decrease in the number of arousals [9 (1-41) cf. 16 (2-74), p = 0.02], decrease in the number of awakenings [3.5 (0-24) cf. 5.5 (1-24), p < 0.05], increase of REM [9% (0-31) cf. 4% (0-23), p < 0.05] and increase of SWS [3% (0-16) cf. 1% (0-10), p < 0.05]. An important output of this work is the confirmation that the patient-ventilator asynchrony was significantly lower in PAV [24 ± 15 cf. PSV 53 ± 59, p = 0.02], which correlates significantly with the number of arousals / h [R^2 = 0.65, p = 0.0001], which can lead to sleep fragmentation and its poor quality. This is in contradiction with the prospective Greek trial by Alexopoulo et al. [40], which compared the effect of patient-ventilator synchronisation on the quality of sleep in PSV / PAV + (= PAV with load adjustable gain factor) modes on 14 patients. Although a statistically significant decrease in asynchrony was confirmed [PAV+ 5.1 (1.1-17.1 / h) cf. PSV 43.0 (3.8-442.5 / h), p = 0.019], it was without a statistically significant impact on the change in sleep architecture N1 [PAV+ 59.7% (16.9 ± 96.2) cf. PSV 63.7% (12.4 ± 97.6), p = 0.754], N2 [PAV+ 31.1% (0.7 ± 73.2) cf. PSV 5.0% (0.0 ± 65.8), p = 0.182], SWS [PAV+ 0.0% (0.0 ± 2.5) cf. PSV 0.0 (0.0-1.9), p = 0.600], REM [PAV+ 0.0% (0.0 ± 8.4) cf. PSV 5.8% (0.0 ± 21.9), p = 0.021]. The primary aim of another Greek trial [41] was to compare the specific setting of ventilation parameters: To verify the effects of the $PAV_{(base/high)}$ + / $PSV_{(base/high)}$ and PAV + modes on the quality of sleep in 17 patients (who were showing good synchronisation with PSV mode). The trial confirms that no significant differences in the quality of sleep and sleep architecture was demonstrated in patients with good primary PSV synchronisation. Delisle et al. [42] evaluated the effects of the NAVA / PSV ventilation modes on the quality of sleep in 14 patients. NAVA showed statistically more significant differences in the evaluated sleep parameters than PSV: SWS [NAVA 20.5% (16-25) cf. PSV 16.5% (17-20), p = 0.001], REM [NAVA 16.5 % (13-29) cf. PSV 4.5 % (3-11), p= 0.001], sleep fragmentation [NAVA 17.5 (8-21.5) cf. PSV 33.5 (25-54), p = 0.001], sleep efficiency (SE) [NAVA 73.5 % (52.5-77) cf. PSV 44 % (29-73.5), p = 0.001]. Also, this intelligent mode is associated with a significant reduction in apnea occurrence [NAVA 0 / h cf. PSV 10.5 ± 11 / h, p = 0.005] and decrease of the ineffective patient effort [NAVA 0 / h cf. PSV 24 ± 23 / h, p = 0.001). Two trials were found, which compare the effects of non-invasive ventilation and spontaneous ventilation on the quality of sleep. A French trial by Roche-Campo et al. [43] confirmed the changes on 16 weaning patients with tracheotomy only in the selected parameters: TST (total sleep time) [NIV (non-invasive ventilation) 183 min (133-211) cf. SB (spontaneous breathing) 132 (28-192), p = 0.04], sleep efficiency (SE) [NIV 44% (9-63) cf. SB 61% (38-74), p = 0.04]. Other parameters without significant difference: N1 and N2 [NIVS 67% cf. SB 68%, p = 0.36], SWS [NIVS 27% cf. SB 16%, p = 0.57], sleep fragmentation [NIV 25 cf. SB 23, p = 0.65]. On the contrary, the Italian trial by Fanfulla et al. [44] in 22 patients did not confirm significant changes in the sleep architecture among patients with spontaneous ventilation and NIV. It states that although there was a higher number of ineffective efforts on the NIV (45.3 ± 66), they caused only a low number of arousals (3.4 ± 4.9), which was not statistically significant. A French trial by Córdoba-Izquierdo et al. [45] carried out in 24 patients with respiratory failure examined whether the ventilator type (ventilator conventionally used in ICU in NIV mode cf. dedicated ventilator for NIV mode) has an effect on the quality of sleep. A significant decrease in the patient-ventilator asynchrony while the

conventional ventilator was used was confirmed [conv. 34 (15-76) cf. dedicated 174 (43-279), p = 0.02] and a lower occurrence of ineffective effort [conv. 2 (0-13 / h) cf. dedicated 34 (15-125), p = 0.04], which has a positive effect on the decrease of sleep fragmentation [conv. 14% (7.0-22) cf. dedicated 28% (17-44), p = 0.02], no significant effect on other parameters was observed: N1 [conv. 8.3 % cf. dedicated 4.4%, p = 0.30], N2 [conv. 36% cf. dedicated 34%, p = 0.82], SWS (slow wave sleep) [conv. 33% cf. dedicated 38%, p = 0.69], REM [conv. 10% cf. dedicated 15%, p = 0.91].

Discussion

A very important factor in the evaluation of trials is the limitation connected with the variability in the design of trials, which can be misleading in comparison for many reasons: 1) different patient groups with basic severity of underlying disease (= different approaches within the ventilation strategy and support) 2) differentiation of used ventilation modes and absence of more detailed parameters of mechanical ventilation 3) the method of ensuring the airway itself (endotracheal tube, tracheotomy, mask) 4) effects of sedation, its type and approaches (almost no patient requiring mechanical ventilation is not completely sedated) 5) other factors associated with the ICU environment (noise, light, nursing interventions).

Regardless of methodological difficulties, the data analysed suggest that ventilation mode and its setting can affect the quality of sleep through various mechanisms [33, 34, 36, 39, 42]. Parthasarathy and Tobin [33] suggest that PSV is connected with a higher occurrence of apnea, which leads to hypoxia and hypercapnia connected with increased respiratory effort. These three factors may lead to greater sleep fragmentation and poor quality of sleep. Andréjak et al. [36] state that choosing a suitable ventilation mode can significantly reduce the work of breathing muscles and thus improve the quality of sleep. Many of the works studied were focused on patient-ventilator asynchrony as a source of sleep fragmentation (arousal + awakening). The occurrence of arousal, awakening (= sleep fragmentation) that has arisen in causal connection with mechanical ventilation according to the American Association of Sleep Medicine (AASM) [46] were considered secondary to apnoea when occurring within three cycles and / or 15 s after a respiratory event. Two trials [33, 39] show that asynchrony is significantly bound to ventilation mode and correlates with the number of arousals ($r^2 = 0.65$, p = 0.0001) and awakenings (r = 0.66, p = 0.01). A trial by Fanfula et al. [44] and a trial by Cabello et al. [35] state that patient-ventilator asynchrony causes < 10% of sleep fragmentation. A trial by Cordoba-Izquierdo et al. [45] states, that asynchrony causes 19% of sleep fragmentation. Two trials [39, 42] demonstrate that advanced ventilation modes PAV, NAVA lead to improved quality of sleep compared to the conventional mode by improving synchronisation between patient and ventilator. In contrast, two Greek trials [40, 41] refute this hypothesis and suggest that although the PAV (+) mode is connected with a significant decrease in asynchrony, it has no effect on sleep fragmentation, and the specific mode setting did not reflect the improvement in sleep architecture. One of the main determinants influencing patient-ventilator synchronisation is sedation. In current clinical practice, the effort to minimise its depth is predominant, which may be very closely related to the patient-ventilator interference. There are trials that significantly confirm its effect on sleep architecture [47, 48]. There is also a growing number of trials that focus not only on the method and type of sedation but also on the different types of approaches (protocol-based sedation, spontaneous awakening trial / spontaneous breathing trial) that can significantly affect the length of artificial ventilation [49, 50]. It is uncertain, how these different approaches affect sleep architecture. A Japanese trial [51] suggests that diurnal interruption of sedation has a positive influence on sleep architecture (causing an increase in SWS and REM). To assess the effects of individual approaches on the quality of sleep, further research is needed. Two trials [43, 44] compare the effect of non-invasive ventilation and spontaneous breathing. Fanfulla et al. [44] demonstrates that mechanical ventilation is not the primary source of sleep disorders and, in his trial, lists the association in relation to the severity of the disease (assessed by SAPS score) [daytime sleep r = 0.51, p < 0.05, sleep efficiency r = 0.5, p < 0.05] and increased pH, which significantly affects sleep architecture. Roche-Campo et al. [43] adds that the method of ensuring the airway alone can be a significant precipitating factor causing sleep disturbances. This is in line with other examined works; where ensuring and managing the airway can be a significant stress factor, which can lead to neuropsychological damage in the patient [52, 53]. Although the findings show that the patient's connection to non-invasive ventilation does not have a key impact on sleep architecture, the authors agree that they can reduce patient effort, improve gas exchange and thus improve their quality of sleep in a selected group of patients (especially during the first few days of discontinuation). Some of the examined works (5 trials) set the noise impact on sleep fragmentation as a partial aim [35, 39, 42, 44, 45]. Noise-related sleep fragmentation (arousal, awakening) is thus evaluated if it is occurred within 3 s after the noise increase $\geq$ 10 dB [16, 54]. Bosma et al.

[39] states that although noise may contribute to sleep disorders, it does not have a significant effect and is not dependent on the type of ventilation mode. Delisle et al. [42] demonstrates that in PSV mode, noise caused 18% of sleep fragmentation, and in NAVA, these changes were recorded at 21%. Cabello et al. [35] suggests that sleep fragmentation associated with an increase in noise was reported in 14%, and that suction used on patient causes only 1% of fragmentation. Fanfulla et al. [44] provides evidence that there is no significant difference between spontaneous breathing and mechanical ventilation regarding the occurrence of noise-related sleep fragmentation and the occurrence is around 3 events per hour. Córdoba-Izquierdo et al. [45] states that the occurrence of sleep fragmentation was statistically significantly higher with a conventional ventilator due to higher noise levels. These findings are in line with the results of 2 trials [16, 54], which indicate that environmental factors are overestimated in relation to sleep disorders. Gabor et al. [54] identified that the increase of noise level by 10 dBA was recorded at 36.5 ± 20.1 / h and caused 20.9 ± 11.3% awakenings. The cause of most of the remaining awakenings (68.1 ± 9.7%) was not identified. An American descriptive trial [16] arrives at similar results, when it states that noise is partly responsible for changes in sleep architecture; however, it is not the principal cause of sleep fragmentation (11.5 ± 11.8% of arousals and 17.0% awakenings).

Limitations of the study and recommendations. This study only includes findings published in the English language and in databases available to us. The quality of the present literary evidence is limited by a lower number of works. Critically assessing the level of the evidence quality, it can be stated that the variability in the design of the trials is a serious limitation of the review. Differences in quality sleep assessment methodology in individual trials do not allow for a full comparative systematic statistical meta-analysis.

Contribution to practice

- Sleep disorders are very frequent among all intensive care unit patients (compared to the general ward patient population)
- Sleep deprivation and disturbed sleep quality have clear and straightforward consequences for patients' level of distress
- Interventions improving the quality of sleep could affect the global critical care outcome of intensive care unit survivors and should be a part of good quality clinical practice in the future
- New ventilation modes can reduce the occurrence of patient-ventilator asynchrony, thereby improving the quality of sleep
- Connecting the patient to the ventilator for the night during prolonged weaning may positively affect the quality of sleep in the selected group of patients
- Adequate setting of ventilation parameters based on patient needs can help sustain sleep

Conclusion

Lack of sleep of adequate quality and length in an ICU is a significant negative factor affecting the quality of provided care. The influence of mechanical ventilation on the quality of sleep is not entirely unambiguous. There is a consensus in the literature that mechanical ventilation is probably not the main factor causing sleep disruptions, but an appropriate ventilation strategy can help to improve its quality. Minimising patient-ventilator asynchrony minimises harmful effects and one of the ways to address the problem of this interaction is to use new ventilation modes that are adapted to patient effort while preserving its variability. In addition, the trials have also confirmed that noise is overestimated in relation to sleep fragmentation. Many other quality trials would be necessary to confirm this fact.

Conflict of interest

Nothing to declare

References

1. Figueroa-Ramos MI, Arroyo-Novoa CM, Lee KA, Padilla G, Puntillo KA. Sleep and delirium in ICU patients: a review of mechanisms and manifestations. Intensive Care Med 2009; 35: 781-795. doi: 10.1007/s00134-009-1397-4
2. Roche Campo F, Drouot X, Thille AW, Galia F, Cabello B, d'Ortho MP, et al. Poor sleep quality is associated with late noninvasive ventilation failure in patients with acute hypercapnic respiratory failure. Crit Care Med 2010; 38: 477-485. doi: 10.1097/CCM.0b013e3181bc8243
3. Desai SV, Law TJ, Needham DM. Long-term complications of critical care. Crit Care Med 2011; 39: 371-379. doi: 10.1097/CCM.0b013e3181fd66e5
4. Leung RS, Bradley TD. Sleep apnea and cardiovascular disease. Am J Respir Crit Care Med 2001; 164: 2147-2165. doi: 10.1164/ajrccm.164.12.2107045
5. DeKeyser Ganz F. Sleep and immune function. Crit Care Nurse 2012; 32: e19-25. doi: 10.4037/ccn2012689
6. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. Lancet 1999; 354: 1435-1439. doi: 10.1016/S0140-6736(99)01376-8
7. Mostaghimi L, Obermeyer WH, Ballamudi B, Martinez-Gonzales D, Benca RM. Effects of sleep deprivation on wound healing. J Sleep Res 2005; 14: 213-219. doi: 10.1111/j.1365-2869.2005.00455.x
8. Wu L, Sun D. Sleep duration and falls: a systematic review and meta-analysis of observational studies. J Sleep Res 2017; 26: 293-301. doi: 10.1111/jsr.12505

9. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. Sleep 2010; 33: 585-592. doi: 10.1093/sleep/33.5.585
10. Friese RS. Sleep and recovery from critical illness and injury: a review of theory, current practice, and future directions. Crit Care Med 2008; 36: 697-705. doi: 10.1097/CCM.0B013E3181643F29
11. Gallicchio L, Kalesan B. Sleep duration and mortality: a systematic review and meta-analysis. J Sleep Res 2009; 18: 148-158. doi: 10.1111/j.1365-2869.2008.00732.x
12. Parsons EC, Kross EK, Caldwell ES, Kapur VK, McCurry SM, Vitiello MV, et al. Post-discharge insomnia symptoms are associated with quality of life impairment among survivors of acute lung injury. Sleep Med 2012; 13: 1106-1109. doi: 10.1016/j.sleep.2012.05.010
13. Parthasarathy S, Tobin MJ. Sleep in the intensive care unit. Intensive Care Med 2004; 30: 197-206. doi: 10.1007/s00134-003-2030-6
14. Boyko Y, Ørding H, Jennum P. Sleep disturbances in critically ill patients in ICU: how much do we know? Acta Anaesthesiol Scand 2012; 56: 950-958. doi: 10.1111/j.1399-6576.2012.02672.x
15. Cooper AB, Thornley KS, Young GB, Slutsky AS, Stewart TE, Hanly PJ. Sleep in critically ill patients requiring mechanical ventilation. Chest 2000; 117: 809-818. doi: 10.1378/chest.117.3.809
16. Freedman NS, Gazendam J, Levan L, Pack AI, Schwab, RJ. Abnormal sleep/wake cycles and the effect of environmental noise on sleep disruption in the intensive care unit. Am J Respir Crit Care Med 2001; 163: 451-457. doi: 10.1164/ajrccm.163.2.9912128
17. Silber MH, Ancoli-Israel S, Bonnet MH, Chokroverty S, Grigg-Damberger MM, Hirshkowitz M, et al. The visual scoring of sleep in adults. J Clin Sleep Med 2007; 3: 121-131
18. Drouot X, Roche-Campo F, Thille AW, Cabello B, Galia F, Margarit L, et al. A new classification for sleep analysis in critically ill patients. Sleep Med 2012; 13: 7-14. doi: 10.1016/j.sleep.2011.07.012
19. Watson PL, Pandharipande P, Gehlbach BK, Thompson JL, Shintani AK, Dittus BS, et al. Atypical sleep in ventilated patients: empirical electroencephalography findings and the path toward revised ICU sleep scoring criteria. Crit Care Med 2013; 41: 1958-1967. doi: 10.1097/CCM.0b013e31828a3f75
20. Ambrogio C, Koebnick J, Quan SF, Ranieri M, Parthasarathy S. Assessment of sleep in ventilator-supported critically ill patients. Sleep 2008; 31: 1559-1568
21. Drouot X, Quentin S. Sleep neurobiology and critical care illness. Crit Care Clin 2015; 31: 379-391. doi: 10.1016/j.ccc.2015.03.001
22. Weinhouse GL, Schwab RJ. Sleepin the critically ill patient. Sleep 2006; 29: 707-716. doi: 10.1093/sleep/29.5.707
23. Pisani MA, Friese RS, Gehlbach BK, Schwab RJ, Weinhouse GL, Jones SF. Sleep in the intensive care unit. Am J Respir Crit Care Med 2015; 191: 731-738. doi: 10.1164/rccm.201411-2099CI
24. Hu RF, Jiang XY, Chen J, Zeng Z, Chen XY, Li Y, et al. Non-pharmacological interventions for sleep promotion in the intensive care unit (Review). Cochrane Database Syst Rev 2015; (10): CD008808. doi: 10.1002/14651858.CD008808.pub2
25. Norton C, Flood D, Brittin A, Miles J. Improving sleep for patients in acute hospitals. Nurs Stand 2015; 29: 35-42. doi: 10.7748/ns.29.28.35.e8947
26. Elliott R, McKinley S. The development of a clinical practice guideline to improve sleep in intensive care patients: a solution focused approach. Intensive Crit Care Nurs 2014; 30: 246-256. doi: 10.1016/j.iccn.2014.04.003
27. Poongkunran C, John SG, Kannan AS, Shetty S, Bime C, Parthasarathy S. A meta-analysis of sleep-promoting interventions during critical illness. Am J Med 2015; 128: 1126-1137. doi: 10.1016/j.amjmed.2015.05.026
28. Ozsancak A, D'Ambrosio C, Garpestad E, Schumaker G, Hill NS. Sleep and mechanical ventilation. Crit Care Clin 2008; 24: 517-531. doi: 10.1016/j.ccc.2008.03.002
29. Rittayamai N, Wilcox E, Drouot X, Mehta S, Goffi A, Brochard L. Positive and negative effects of mechanical ventilation on sleep in the ICU: a review with clinical recommendations. Intensive Care Med 2016; 42: 531-541. doi: 10.1007/s00134-015-4179-1
30. Esteban A, Anzueto A, Alía I, Gordo F, Apezteguía C, Pálizas F, et al. How is mechanical ventilation employed in the intensive care unit? An international utilization review. Am J Respir Crit Care Med 2000; 161: 1450-1458. doi: 10.1164/ajrccm.161.5.9902018
31. Ryan R; Cochrane Consumers and Communication Review Group. Cochrane Consumers and Communication Review Group: data synthesis and analysis [internet]. June 2013 [cited 2018 Jan 12]. Available at: http://cccrg.cochrane.org/sites/cccrg.cochrane.org/files/public/uploads/Analysis.pdf
32. Ryan R, Hill S, Prictor M, McKenzie J; Cochrane Consumers and Communication Review Group. Study Quality Guide [internet]. May 2013 [cited 2018 Jan 20]. Available at: https://cccrg.cochrane.org/sites/cccrg.cochrane.org/files/public/uploads/StudyQualityGuide_May 2013.pdf
33. Parthasarathy S, Tobin MJ. Effect of ventilator mode on sleep quality in critically ill patients. Am J Respir Crit Care Med 2002; 166: 1423-1429. doi: 10.1164/rccm.200209-999OC
34. Toublanc B, Rose D, Glérant JC, Francois G, Mayeux I, Rodenstein D, et al. Assist-control ventilation vs. low levels of pressure support ventilation on sleep quality in intubated ICU patients. Intensive Care Med 2007; 33: 1148-1154. doi: 10.1007/s00134-007-0659-2
35. Cabello B, Thille AW, Drouot X, Galia F, Mancebo J, d'Ortho MP, et al. Sleep quality in mechanically ventilated patients: comparison of three ventilatory modes. Crit Care Med 2008; 36: 1749-1755. doi: 10.1097/CCM.0b013e3181743f41
36. Andréjak C, Monconduit J, Rose D, Toublanc B, Mayeux I, Rodenstein D, et al. Does using pressure-controlled ventilation to rest respiratory muscles improve sleep in ICU patients? Respir Med 2013; 107: 534-541. doi: 10.1016/j.rmed.2012.12.012
37. Blanch L, Villagra A, Sales B, Montanya J, Lucangelo U, Luján M, et al. Asynchronies during mechanical ventilation are associated with mortality. Intensive Care Med 2015; 41: 633-641. doi: 10.1007/s00134-015-3692-6
38. Thille AW, Rodriguez P, Cabello B, Lellouche F, Brochard L. Patient-ventilator asynchrony during assisted mechanical ventilation. Intensive Care Med 2006; 32: 1515-1522. doi: 10.1007/s00134-006-0301-8
39. Bosma K, Ferreyra G, Ambrogio C, Pasero D, Mirabella L, Braghiroli A, et al. Patient-ventilator interaction and sleep in mechanically ventilated patients: pressure support versus proportional assist ventilation. Crit Care Med 2007; 35: 1048-1054. doi: 10.1097/01.CCM.0000260055.64235.7C
40. Alexopoulou C, Kondili E, Plataki M, Georgopoulos D. Patient-ventilator synchrony and sleep quality with proportional assist

and pressure support ventilation. Intensive Care Med 2013; 39: 1040-1047. doi: 10.1007/s00134-013-2850-y

41. Alexopoulou C, Kondili E, Vakouti E, Klimathianaki M, Prinianakis G, Georgopoulos D. Sleep during proportional-assist ventilation with load-adjustable gain factors in critically ill patients. Intensive Care Med 2007; 33: 1139-1147. doi: 10.1007/s00134-007-0630-2
42. Delisle S, Ouellet P, Bellemare P, Tétrault JP, Arsenault P. Sleep quality in mechanically ventilated patients: comparison between NAVA and PSV modes. Ann Intensive Care 2011; 1: 42. doi: 10.1186/2110-5820-1-42
43. Roche-Campo F, Thille AW, Drouot X, Galia F, Margarit L, Córdoba-Izquierdo A, et al. Comparison of sleep quality with mechanical versus spontaneous ventilation during weaning of critically ill tracheostomized patients. Crit Care Med 2013; 41: 1637-1644. doi: 10.1097/CCM.0b013e318287f569
44. Fanufulla F, Ceriana P, D'Artavilla Lupo N, Trentin R, Frigerio F, Nava S. Sleep disturbances in patients admitted to a step-down unit after ICU discharge: the role of mechanical ventilation. Sleep 2011; 34: 355-362. doi: 10.1093/sleep/34.3.355
45. Córdoba-Izquierdo A, Drouot X, Thille AW, Galia F, Roche-Campo F, Schortgen F, et al. Sleep in hypercapnic critical care patients under noninvasive ventilation: conventional versus dedicated ventilators. Crit Care Med 2013; 41: 60-68. doi: 10.1097/CCM.0b013e31826764e3
46. Iber C, Ancoli-Israel S, Chesson A, Quan SF. The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications. 1st ed. Westchester, Illinois: American Academy of Sleep Medicine; 2007
47. Oto J, Yamamoto K, Koike S, Onodera M, Imanaka H, Nishimura M. Sleep quality of mechanically ventilated patients sedated with dexmedetomidine. Intensive Care Med 2012; 38: 1982-1989. doi: 10.1007/s00134-012-2685-y
48. Kondili E, Alexopoulou C, Xirouchaki N, Georgopoulos D. Effects of propofol on sleep quality in mechanically ventilated critically ill patients: a physiological study. Intensive Care Med 2012; 38: 1640-1646. doi: 10.1007/s00134-012-2623-z
49. Kress JP, Pohlman AS, O'Connor MF, Hall JB. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. N Engl J Med 2000; 342: 1471-1477. doi: 10.1056/NEJM200005183422002
50. Girard TD, Kress JP, Fuchs BD, Thomason JW, Schweickert WD, Pun BT, et al. Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (Awakening and Breathing Controlled trial): a randomised controlled trial. Lancet 2008; 371: 126-134. doi: 10.1016/S0140-6736(08)60105-1
51. Oto J, Yamamoto K, Koike S, Imanaka H, Nishimura M. Effect of daily sedative interruption on sleep stages of mechanically ventilated patients receiving midazolam by infusion. Anaesth Intensive Care 2011; 39: 392-400
52. Novaes MAFP, Knobel E, Bork AM, Pavão OF, Noguiera-Martins LA, Ferraz MB. Stressors in ICU: perception of the patient, relatives and health care team. Intensive Care Med 1999; 25: 1421-1426. doi: 10.1007/s001340051091
53. Mehta S, Hill NS. Nonivasive ventilation. Am J Respir Crit Care Med 2001; 163: 540-577. doi: 10.1164/ajrccm.163.2.9906116
54. Gabor JY, Cooper AB, Crombach SA, Lee B, Kadikar N, Bettger HE, et al. Contribution of the intensive care unit environment to sleep disruption in mechanically ventilated patients and healthy subjects. Am J Respir Crit Care Med 2003; 167: 708-715. doi: 10.1164/rccm.2201090