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Polysomnographic evaluation of sleep structure changes in patients with suspected OSA**

Ocena polisomnograficzna zmian struktury snu u pacjentów z podejrzeniem zespołu zaburzeń oddychania w czasie snu o charakterze bezdechu obturacyjnego

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Key words

OSA, polysomnography, sleep structure, light sleep, deep sleep, REM, AHI

Słowa kluczowe

OSA, polisomnografia, struktura snu, sen płytki, sen głęboki REM, AHI

S u m m a r y

Introduction. Recent polysomnography (PSG) studies show the same sleep structure changes in OSA patients: longer the light sleep, shorter or lack of the deep sleep and REM.

Aim. The aim of the study was to analyze correlation between sleep structure and breathing sleep disturbances.

Material and methods. We analyzed 907 polysomnograms of patients with suspected OSA, they were divided into 2 groups based of AHI: non-OSA (AHI < 5) and OSA (AHI ≥ 5). According to AHI OSA group was divided into: mild ($5 \leq$ AHI < 15), moderate ($15 \leq$ AHI ≤ 30), and severe (AHI > 30). We analyzed duration of sleep stages: light, deep sleep and REM using Statistica 6.1.

Results. We found the statistically significant differences of sleep structure between non-OSA and OSA population in light sleep 76.7 vs 86.45% ($p < 0.0001$); deep sleep 17.53 vs 14.35% ($p < 0.0001$); REM 5.87 vs 5.77% ($p < 0.05$). In OSA group sleep structure was classified in AHI dependent groups: mild (light sleep – 79.87%; deep sleep – 14.35%; REM – 5.77%); moderate (light sleep – 82.73%; deep sleep – 12.64%; REM – 4.63%); severe (light sleep – 86.45%; deep sleep – 9.54%; REM – 4.01%).

Conclusions. We found longer the light sleep, shorter deep and REM sleep in OSA, and also in non-OSA shorter deep sleep and REM comparing to physiological sleep what may be due to worse sleep laboratory conditions compared with home and may be limiting for PSG.

S t r e s z c z e n i e

Wstęp. Wyniki polisomnografii (PSG) pokazują zmiany struktury snu u chorych z zaburzeniami oddychania w czasie snu o charakterze bezdechu obturacyjnego (OSA): dłuższy sen płytki, krótszy sen głęboki i REM lub ich brak.

Cel pracy. Celem badania była analiza korelacji pomiędzy strukturą snu a zaburzeniami oddychania.

Materiał i metody. Przeanalizowaliśmy 907 PSG pacjentów z podejrzeniem OSA podzielonych na dwie grupy według AHI (ang. *Apnea Hypopnea Index*): bez OSA (AHI < 5) i z OSA (AHI ≥ 5). Pacjentów z OSA podzielono na stadia: łagodne ($5 \leq$ AHI < 15), umiarkowane ($15 \leq$ AHI ≤ 30) i ciężkie (AHI > 30). Analizowano czas trwania poszczególnych stadiów snu za pomocą Statistica 6.1.

Wyniki. Występowały statystycznie istotne różnice pomiędzy grupami z OSA vs bez OSA w procentowym występowaniu snu płytkiego – 76,7 vs 86,45%; głębokiego – 17,53 vs 14,35% (dla obu $p < 0,0001$) oraz REM – 5,87 vs 5,77% ($p < 0,05$). W grupie z OSA strukturę snu oceniono w stadiach: łagodnym (sen płytki – 79,87%; głęboki – 14,35%; REM – 5,77%); umiarkowanym (sen płytki – 82,73%; głęboki – 12,64%; REM – 4,63%) oraz ciężkim (sen płytki – 86,45%; głęboki – 9,54%; REM – 4,01%).

Wnioski. Stwierdzono dłuższy sen płytki, krótszy głęboki i REM w grupie z OSA, a w grupie bez OSA krótszy sen głęboki i REM w porównaniu do wartości fizjologicznych, czego przyczyną mogą być gorsze i niefizjologiczne warunki snu w pracowni polisomnograficznej ograniczające badanie.

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**This work was supported by CMKP grants (Project No: 501-3-40-10-11).

INTRODUCTION

Normal sleep architecture is responsible for effective rest. It is well known that deep sleep of NREM stage and REM sleep are responsible for the proper functioning of the body. The physiology of sleep stages percentage composition is the following for NREM sleep: light sleep consists of stage 1 – 5-10% and stage 2 – 45-55%, deep sleep consists of stages 3 + 4 (in new classification the 4th stage of NREM sleep has been included within stage 3; this stage is also called slow wave sleep [SWS]) (1) and takes 10-20% of total sleep time.

REM sleep is estimated in physiology to take approximately 20% of total sleep time. Excessive daytime sleepiness is a symptom common to patients with OSA and it results in many psychological consequences such as: worse quality of life, worse concentration, increased risk of motor incidence, decreased work capacity. Previous studies have shown that daytime sleepiness is more related to sleep fragmentation and to intermittent hypoxemia in OSA (2).

Sleep deprivation has also other consequences, current data suggest the relationship between sleep restriction and alterations in glucose metabolism, disregulation of appetite, decreased energy expenditure (3).

The results of many studies show that sleep disturbances are observed in patients presenting sleep-disordered breathing (SBD) primarily of obstructive sleep apnea syndrome (OSA). Usually it is sleep fragmentation and extension of light sleep and reduced deep sleep and REM. Many studies show that hypnogram of OSA patients usually presents absence of slow wave sleep and REM (2, 4). Consequences of sleep structure disturbances may underlie many clinical complications of OSA.

AIM

The aim of the study was to analyze a correlation between sleep structure and breathing sleep disturbances and to score the change in the length of sleep stages depending on the severity of the disease based on AHI. We also wanted to see the correlation between AHI and the percentage occurrence of various stages of sleep.

MATERIAL AND METHODS

Patients

We examined retrospectively 907 (n = 907) polysomnograms recruited from patients (both sexes) referred to a sleep laboratory for suspected sleep apnea. We included patients with clinical suspicion of OSA, obese patients before bariatric surgery, patients before laryngological procedures, and patients who snored regularly. Patients were referred to the sleep laboratory by physicians of many specialties: family doctors, surgeons, internists, otolaryngologists.

The reasons for referring patients to clinical polysomnography were as follows:

- snoring,
- snoring with apnea observed bypersons sleeping in one room with the patient,
- abnormal nasal patency, and throat – before any surgery,
- excessive daytime sleepiness,
- insomnia,
- heart problems, such as hypertension resistant to treatment,
- obesity,
- prior to the surgery of obesity (bariatric surgery).

Anthropometric characteristics of the group are listed in table 1.

Table 1. Anthropometric characteristics of the group.

Mean values	Women n = 271	Men n = 636	Total n = 907
Mean age (SD)*	51.9 (14.7)	51.9 (13.1)	51.9 (13.6)
Mean BMI kg/m2 (SD)	35.2 (10.5)	31.3 (7.3)	32.5 (8.6)

*Standard deviation

Polysomnographic studies were performed and evaluated in accordance with current international standards (5-7).

PSG included the following variables: electroencephalograms, electrooculograms, electromyelograms of submental muscules, electrocardiogram, airflow (nasal and oral), chest and abdominal efforts, snoring (microphone) and arterial oxyhemoglobin saturation and pulse (finger probe).

Polysomnographic recordings were evaluated with respect to:

- amount of disordered breathing during sleep,
- type of a disorder: obstructive sleep apnea, mixed, central, hypopnea,
- AHI (Apnea Hypopnea Index),
- disease severity based on AHI: (mild form of $5 \leq$ AHI < 15, moderate $15 \leq$ AHI ≤ 30; severe AHI > 30),
- the number of desaturations,
- the average oxygen saturation (Sa av),
- minimum oxygen saturation (Sa min),
- heart rate (HR),
- the length of non REM (non-rapid eye movement) sleep composed of light sleep stages 1 and 2 (1 + 2), and composed of deep sleep stages 3 and 4 (3 + 4),
- the length of REM sleep (rapid eye movement).

Criteria and definitions used in polysomnography

Characteristic of sleep stages

Stage 1 sleep – EOG-slow rolling eye movements. EEG-low voltage, mixed frequency; may be θ rhythm 2-7 Hz, up to 50-75 uV range; vertex sharp waves (200 uV). θ waves 4-7 Hz; low voltage, mixed frequency backgrounds; often appear as sharp vertex waves; EMG tonic activity, slight decrease compared with waking.

Stage 2 sleep – EOG slow rolling eye movement occasionally near sleep onset. EEG-low voltage, mixed frequency. Sleep spindles-bursts of 12-14 Hz activity, $\geq$ 0.5 s long, no amplitude requirement. K complexes

sharp negative wave followed by positive component, ≥ 0.5 s long, no amplitude requirement. EMG-low level tonic activity.

Stage 3 sleep – EOG-reflects EEG. EEG – δ rhythm takes 20-50% of epoch (30 sec of sleep), high amplitude waves (higher than 75 uV) with low frequency (≤ 2 Hz). EMG-tonic activity, low level).

Stage 4 sleep – usually described as a part of stage 3, the difference is related to amount of δ rhythm (more than 50%).

REM sleep – EOG-phasic REMs. EEG-low voltage, mixed frequency, sawtooth waves, θ activity, slow α activity. EMG-tonic suppression, phasic twitches (8).

Characteristic of respiratory events

AHI (Apnea Hypopnea Index) was used as the main criterion for the OSA diagnosis. AHI was defined as the number of apneas and hypopneas per hour of sleep. We used to identify OSA AHI ≥ 5.

Using AHI criteria we divided the AHI ≥ 5 group into three severity stages:

- mild OSA 5 ≤ AHI < 15,
- moderate OSA 15 ≤ AHI ≤ 30,
- severe OSA AHI > 30.

Obstructive sleep apnea – the complete cessation of flow for ≥ 10 sec with continued respiratory effort throughout the apnea.

Hypopnea – minimum 30% reduction of air flow or thoracoabdominal movement for ≥ 10 sec. (5).

Central apnea – the complete cessation of respiratory movement and flow for ≥ 10 sec.

Mixed apnea – the complete cessation of flow for ≥ 10 sec with respiratory effort initially absent, but returning midway through the apnea (5-7).

Project was approved by the ethics committee at The Centre of Postgraduate Medical Education.

Statistical analysis

Statistical data was developed using the Statistics for 6.1 – Property CMKP Nr. AXAP306C000410FA and included:

a) descriptive statistic on the parameters (mean value, standard deviation),
b) correlations between the assessed parameters (r-Pearson correlation),
c) rate differences in the evaluated parameters (t-student test for dependent and independent samples, test ”z”, Ch ^ 2NW test, Ch ^ 2 Pearson test, Ch ^ 2with Yate’sa correction).

We considered statistically significant 95% confidence level ($p < 0.05$).

RESULTS

Retrospectively analyzed polysomnograms were performed for the patients 51.9 (13.6) years old (mean age) and mean BMI 32.5 (8.6). BMI > 30 indicates obesity. We compared sleep structure in group with AHI ≥ 5 (OSA-group) to the group with AHI < 5 (non-OSA group).

In OSA group we observed statistically significant sleep disturbances in comparison to non-OSA group, extension of the light sleep (stages 1 + 2) ($p < 0.0001$), reduction of the deep sleep (stages 3 + 4) ($p < 0.0001$) and REM sleep reduction ($p < 0.05$) (tab. 2).

Table 2. Percentage distribution of the various stages of sleep and the significance of differences in percentage distributions of sleep in group with AHI < 5 and AHI ≥ 5.

Sleep stages in percentage of total sleep	AHI < 5	AHI ≥ 5	p
(1 + 2)% (SD)	76.6 (15.17)	83.07 (14.51)	< 0.0001
(3 + 4)% (SD)	17.53 (13.26)	12.12 (12.96)	< 0.0001
REM% (SD)	5.87 (9.05)	4.81 (6.66)	< 0.05

We also determined correlations between the various sleep stages as a percentage of total sleep.

In AHI ≥ 5 group we found a statistically significant positive correlation between AHI and light sleep % (1 + 2)% ($p < 0.001$; $r = 0.14$ [tab. 3, fig. 1]) and a negative correlation between AHI and deep sleep % (3 + 4)% ($p < 0.05$; $r = -0.09$ [tab. 3, fig. 2]). We also found a negative correlation between AHI and REM sleep as a percentage of total sleep (REM%) ($p < 0.005$; $r = -0.12$ [tab. 3, fig. 3]).

Table 3. Correlations between AHI and percentage values of the various sleep stages.

Av AHI/Sleep stages (%)	Average	Standard deviation	n	r	t	p
AHI	28.80	22.06				
(1 + 2)%	83.07	14.51	557	0.1426	3.3948	< 0.001
(3 + 4)%	12.12	12.96	557	-0.0959	-2.2708	< 0.05
REM%	4.81	6.66	557	-0.1240	-2.9443	< 0.005

Additionally we analyzed sleep structure disturbances including the OSA severity by AHI. We found statistically significant differences in percentage of light sleep (1 + 2) and deep sleep (3 + 4) for the

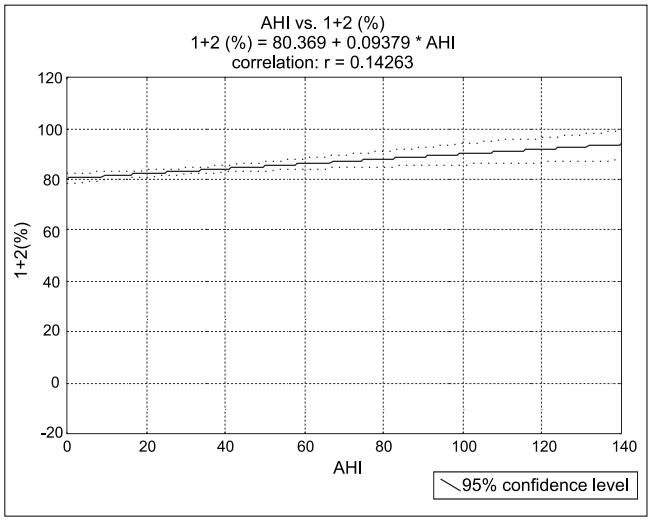

Fig. 1. Correlation AHI vs stages (1 + 2)%.

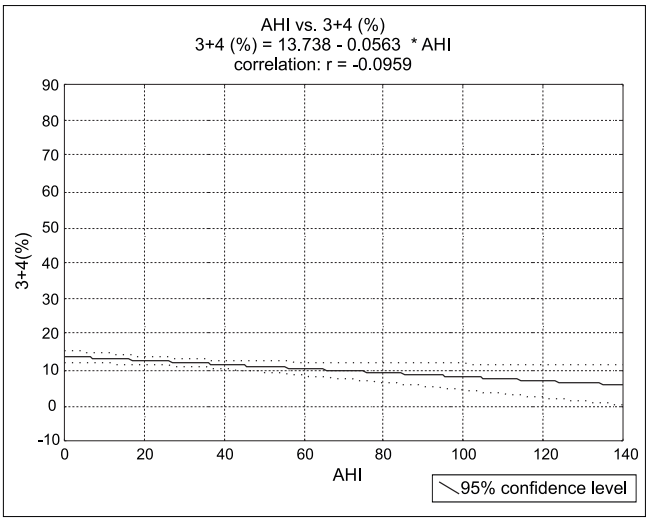

Fig. 2. Correlation AHI vs stages (3 + 4)%.

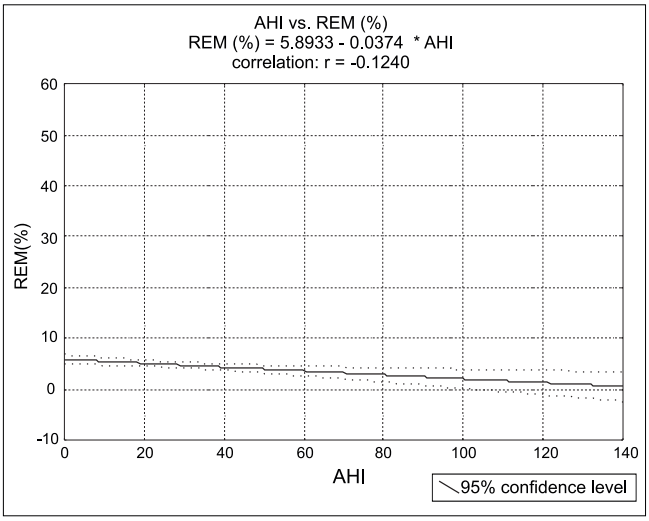

Fig. 3. Correlations AHI vs REM%.

mild ($5 \leq AHI < 15$) ($p < 0.05$; $p < 0.0001$) and moderate ($15 \leq AHI \leq 30$) ($p < 0.01$; $p = 0.0001$) comparing to non-OSA group. In severe OSA stage ($AHI > 30$) comparing to non-OSA group statistically significant differences were found for the light sleep (1 + 2)% ($p < 0.0001$), deep sleep (3 + 4)% ($p < 0.0001$) and for REM sleep ($p < 0.002$) (tab. 4).

DISCUSSION

The sleep structure disturbances characteristic for OSA are associated with the fragmentation caused by arousals and awakenings. Elongation of the light sleep (1 + 2) and shortening or lack of deep sleep (3 + 4) and REM sleep are typical for OSA patients. It was confirmed in OSA patients polysomngraphy studies that their hypnograms often do not contain slow-wave sleep, that is deep sleep and REM sleep (1, 4). The daytime symptoms of OSA (mainly excessive daytime sleepiness) are the direct consequence of the disorders of the sleep structure during the night (9).

In our observations of patients with $AHI \geq 5$ they presented in assessed polysomnographic studies prolongated light sleep (stages 1 + 2) and shortened deep sleep (stages 3 + 4) and REM sleep compared to those with $AHI < 5$. Additionally we described a positive correlation between AHI and the length of light sleep and a negative correlation between AHI and the length of deep sleep and REM sleep. This correlation can explain the severity of daytime sleepiness in more severe stages of OSA.

At the same time it was noted that the group with $AHI < 5$ (non-OSA) had also a disturbed sleep architecture (elongation of the light sleep, reduction of the deep sleep and REM sleep) however the changes were less severe. These changes may be due to sleeping conditions that are different in the polysomnography laboratory and at home. Perhaps the global trend to create at sleep lab conditions similar to home is warranted. Published studies have compared the quality of sleep in the laboratory polysomnography to polysomnography performed at home, which showed that the quality of sleep is better in patients examined at home (10). There are also opinions in opposition to this claim (11).

Disorders of the physiological structure of sleep in people with $AHI < 5$ during PSG studies in the polysomnography laboratory may be a clue to try to implement the diagnostic methods of sleep disordered breathing during sleep, which can be done at home. It is well known that the shortening of sleep can affect the metabolism of the body (3). Experimental studies on young people sleep deprivation resulted in insulin resistance with increased evening cortisol secretion and activation of the sympathetic nervous system (12). The restriction of sleep can, as shown, be associated with a reduced level of leptin, increased level of ghrelin and increased appetite (13). However the causal link between the length, quality of sleep and obesity is far from confirmation (14-16). In the literature, we find the conclusions confirming of an association of obesity with shortening of sleep in both adults and children (17),

Table 4. Comparison of significance of differences between the OSA stages ($5 \leq AHI < 15$; $15 \leq AHI \leq 30$; $AHI > 30$) and non-OSA ($AHI < 5$) group.

Sleep stages in percentage of total sleep	AHI < 5	5 ≤ AHI < 15	p	15 ≤ AHI ≤ 30	p	AHI > 30	p
(1 + 2)% (SD)	76.6 (15.7)	79.87 (15.7)	< 0.05	82.73 (12.05)	< 0.0001	86.45 (14.28)	< 0.0001
(3 + 4)% (SD)	17.53 (13.26)	14.35 (13.91)	< 0.01	12.64 (11.68)	< 0.0001	9.54 (12.47)	< 0.0001
REM% (SD)	5.87 (9.05)	5.77 (6.54)	NS	4.63 (6.09)	NS	4.01 (7.08)	< 0.002

but there are also those that are denying these conclusions (18). An interesting issue is highlighted in the literature the importance of deep sleep in the regeneration of the body through impact not only on the brain, but also on glucose metabolism. Increasing number of reports combines shortening of the length of a deep sleep (SWS – slow wave sleep) with the development of obesity through changes in insulin sensitivity and the regulation of appetite. In published medical literature correlation between BMI and length of deep sleep is noticed (19). In our project the study population had mean BMI > 30, what confirmed obesity. Because the study was retrospective we were not able to observed correlations between BMI changes sleep structure.

CONCLUSIONS

We observed statistically significant differences in sleep structure between non-OSA (AHI < 5) and OSA (AHI ≥ 5) patients. However in non-OSA group we also noticed shorter deep sleep and REM sleep comparing to physiological sleep what may suggest that PSG may interfere with sleep structure also in non-OSA patients. It may be due to worse sleep laboratory conditions compared to the conditions at home and may be limiting for PSG.

In OSA group we confirmed correlations between severity of OSA by AHI and prolongated light (stages 1 + 2) sleep and shortened or lack of deep (stages 3 + 4) sleep an REM sleep.

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received/otrzymano: 10.12.2014
accepted/zaakceptowano: 05.01.2015