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Average and minimum oxygen saturation in patients with suspected OSA as a disease severity index in polysomnographic evaluation

Średnia i minimalna saturacja jako wskaźnik ciężkości choroby u pacjentów z podejrzeniem zespołu zaburzeń oddychania w czasie snu o charakterze bezdechu obturacyjnego (OSA)

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Keywords

OSA, polysomnography, hypoxia, saturation, AHI

Słowa kluczowe

OSA, polisomnografia, hipoksja, saturacja, AHI

S u m m a r y

Introduction. Nocturnal hypoxia is responsible for many obstructive sleep apnea syndrome (OSA) complications, therefore the saturation values-exponents of hypoxia are important for assessing the risk of complications.

Aim. Aim of this work was to compare the oxygen saturation in OSA vs non OSA patients.

Material and methods. We included 907 patients. On the basis of polysomnography (PSG) according to AHI (Apnea-Hypopnea Index) they were divided into 2 groups: OSA (AHI $\geq$ 5) and non OSA (AHI < 5). The OSA group was divided into 3 stages: mild (5 $\leq$ AHI < 15), moderate (15 $\leq$ AHI $\leq$ 30), and severe (AHI > 30). In all patients average (Av SaO_2) and minimum (Min SaO_2) oxygen saturation was evaluated. The outcomes were analyzed by Statistica 6.0.

Results. OSA group (n = 557): Av SaO_2 = 91.69%, Min SaO_2 = 77.21%; non OSA (n = 350): Av SaO_2 = 93.62%, Min SaO_2 = 87.26%. These differences were statistically significant ($p < 0.0001$). For each stage of OSA the mean saturations: mild – Av SaO_2 = 92.93%, Min SaO_2 = 81.83%; moderate – Av SaO_2 = 92.24%, Min SaO_2 = 78.9%; severe – Av SaO_2 = 90.06%, Min SaO_2 = 71.44%. Statistically significant differences were found between Av SaO_2 ($p < 0.05$) and Min SaO_2 ($p < 0.0005$) in the mild and moderate OSA stage and Av SaO_2 and Min SaO_2 in the moderate and severe stage ($p < 0.0001$).

Conclusions. We concluded in more advanced OSA lower Av SaO_2 and Min SaO_2 were observed which is additional to AHI hint to apply the treatment and prevent complications associated with hypoxia.

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

Wstęp. Nocne niedotlenienie jest odpowiedzialne za wiele powikłań zespołu zaburzeń oddychania o charakterze bezdechu obturacyjnego (OSA), dlatego saturacja jako wykładnik wartości niedotlenienia jest istotna dla oceny ryzyka powikłań.

Cel pracy. Celem pracy było porównanie saturacji pacjentów z i bez OSA.

Materiał i metody. Do badania włączono 907 pacjentów. Na podstawie polisomnografii (PSG) podzielono ich wg AHI na 2 grupy: z OSA (AHI $\geq$ 5) i bez OSA (AHI < 5). Grupę OSA podzielono na 3 stadia: łagodne (5 $\leq$ AHI < 15), umiarkowane (15 $\leq$ AHI $\leq$ 30) i ciężkie (AHI > 30). U wszystkich pacjentów oceniano średnią (Av SaO_2) oraz minimalną (Min SaO_2) saturację. Wyniki analizowano za pomocą programu Statistica 6.0.

Wyniki. Grupa OSA (n = 557): Av SaO_2 = 91,69%, Min SaO_2 = 77,21%; grupa bez OSA (n = 350): Av SaO_2 = 93,62%, Min SaO_2 = 87,26%. Różnice te były statystycznie znamienne ($p < 0,0001$). Dla stadiów OSA saturacje wynosiły odpowiednio: łagodne – Av SaO_2 = 92,93%, Min SaO_2 = 81,83%; umiarkowane – Av SaO_2 = 92,24%, Min SaO_2 = 78.9%; ciężkie – Av SaO_2 = 90,06%, Min SaO_2 = 71,44%. Różnice istotne statystycznie stwierdzono między Av SaO_2 ($p < 0,05$) i Min SaO_2 ($p < 0,0005$) w łagodnym i umiarkowanym stadium OSA oraz między Av SaO_2 i Min SaO_2 w umiarkowanym i ciężkim stadium ($p < 0,0001$).

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Wnioski. Niższe wartości Av SaO_2 i Min SaO_2 obserwowano w bardziej zaawansowanych stadiach OSA, może to być dodatkową obok AHI wskazówką do wdrożenia leczenia i w zapobieganiu powikłaniom.

INTRODUCTION

Obstructive sleep apnea (OSA) is an important problem of the developed world (affects more than 4% of male population and 2% women population) (1) and is characterized by repetitive upper airway obstruction during sleep that leads to intermittent hypoxia. Repetitive episodes of oxygen desaturation of 2-4% are a typical symptom of obstructive sleep apnea syndrome (OSA). They are the consequences of respiratory apnea and hypopnea incidents. A unique form of hypoxia with repetitive short cycles of desaturation followed by rapid reoxygenation is termed intermittent hypoxia (IH) and it probably plays a significant role in pathogenesis of cardiovascular complications in OSA (2, 3). In some studies intermittent hypoxia is considered as the main factor involved in cardiovascular remodelling in OSA (4, 5). It has also been noticed that in OSA patients, early signs of atherosclerosis are correlated with hypoxia severity even after adjustment for confounding factors (6). Average and minimum saturation is together with AHI (Apnea-Hypopnea Index) and ODI (Oxygen Desaturation Index) an important predictor of the severity OSA.

Obesity is closely associated with OSA. White adipose tissue is a major secretory and endocrine organ. Obesity induces a chronic low-grade inflammatory state and many of the inflammatory pathways proposed to be activated by intermittent hypoxia in OSA are also activated in adipose tissue (7-9).

In our opinion average and minimum oxygen saturation are indirect markers of hypoxia and help – in addition to AHI – to assess severity of OSA.

AIM

With regard to the important role of night hypoxia in OSA we wanted to compare the average and minimum oxygen saturation in OSA patients (AHI $\geq$ 5) vs non-OSA population (AHI < 5) during sleep in polysomnography (PSG) and see the differences in average and minimum oxygen saturation in these patients for different OSA stages. We also wanted to investigate a possible correlation between both mean values of saturations and AHI.

MATERIAL AND METHODS

We examined retrospectively 907 (n = 907) polysomnograms recruited from patients (both sexes) referred to a sleep laboratory for suspected sleep apnea. We included bariatric patients, patients before laryngological procedures, and patients who snored regularly. Patients were referred to 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 by persons 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 table1.

Table1. Anthropometric characteristics of the group

Parameters	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/m^2 (SD)	35.2 (10.5)	31.3 (7.3)	32.5 (8.6)

SD – standard deviation

Polysomnographic studies were performed and evaluated in accordance to current international standards (10-12).

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 disorders: obstructive sleep apnea, mixed, central, hypopnea,
- AHI number of apnea/hypopnea incidents per one hour of sleep,
- disease severity based on AHI (a mild form of 5 $\leq$ AHI < 15, moderate 15 $\leq$ AHI $\leq$ 30; severe AHI > 30),
- the number of desaturations,
- the average oxygen saturation (Av SaO_2),
- minimum oxygen saturation (Min SaO_2),
- 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).

Statistical analysis included:

- descriptive statistic on the parameters (mean value, standard deviation),
- correlations between the assessed parameters (r-Pearson correlation),

– rate differences in the evaluated parameters (t-Student test for dependent and independent samples, Z-test, Ch^2 NW test, Ch^2 Pearson test, Ch^2 with Yate's correction),
– we considered statistically significant 95% confidence level ($p < 0.05$).

All statistical analyses were carried out using statistical software Statistica version 6.0.

RESULTS

We analyzed 907 patients with suspected OSA. 557 patients with AHI ≥ 5 were treated as the OSA group, which was composed of 155 females and 402 males. The group with AHI < 5 named as the non-OSA group included 350 people consisting of 116 females and 234 males. We compared average (Av SaO_2) and minimum (Min SaO_2) saturation between the OSA group AHI ≥ 5 and the non-OSA AHI < 5 both in women and men.

Depth of hypoxia estimated by average and minimum oxygen saturation was statistically different in the group with AHI ≥ 5 than in the non-OSA for all patients and separately for men and women (tab. 2-4; fig.1-3).

Additionally we compared average and minimum saturation in various stages of OSA severity assessed by AHI. The lowest saturations values were noticed in patients in the severe stage of OSA (Av SaO_2 – 90.06%, Min SaO_2 – 71.44%), higher in the moderate OSA (Av SaO_2 – 92.23%, Min SaO_2 – 78.9%) and in the mild stage of OSA Av SaO_2 – 92.93%, Min SaO_2 – 81.83%) (tab. 5).

Table 2. Average and minimum saturation in patients AHI < 5 and AHI ≥ 5

Parameters	AHI < 5	AHI ≥ 5	p-value in comparison between AHI < 5 and AHI ≥ 5
Number of patients	350	557	
Av SaO_2 in % (SD)	93.62% (3.29)	91.69% (3.81)	p < 0.0001
Min SaO_2 in % (SD)	87.26% (6.26)	77.21% (9.52)	p < 0.0001

Table 3. Average and minimum saturation (SD) in women with AHI < 5 and women with AHI ≥ 5

Parameters	Women with AHI < 5	Women with AHI ≥ 5	p-value in comparison between women with AHI < 5 and AHI ≥ 5
Number of females	116	155	
Av SaO_2 in % (SD)	94.28% (2.77)	91.94% (3.82)	p < 0.0001
Min SaO_2 in % (SD)	88.42% (6.37)	77.77% (9.73)	p < 0.0001

Table 4. Average and minimum saturation (SD) in male with AHI < 5 and with AHI ≥ 5

Parameters	Male with AHI < 5	Male with AHI ≥ 5	p-value in comparison between women with AHI < 5 and AHI ≥ 5
Number of males	234	402	
Av SaO_2 in % (SD)	93.3% (3.48)	91.59% (3.80)	p < 0.0001
Min SaO_2 in % (SD)	87.33% (6.37)	77.0 % (9.44)	p < 0.0001

Table 5. Average and minimum saturation in various stages of severity OSA assessed by AHI

OSA stages by AHI	5 ≤ AHI < 15 mild	15 ≤ AHI ≤ 30 moderate	AHI > 30 severe
Number of patients	201	152	205
Av SaO_2 in % (SD)	92.93% (3.03)	92.24% (3.23)	90.06% (4.3)
Min SaO_2 in % (SD)	81.83% (6.8)	78.9% (7.9)	71.44% (9.95)

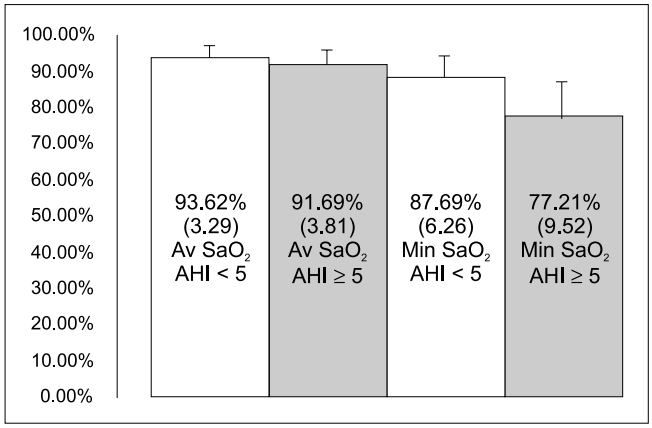

Fig. 1. Average and minimum saturations (SD) in people with z AHI < 5 and AHI ≥ 5

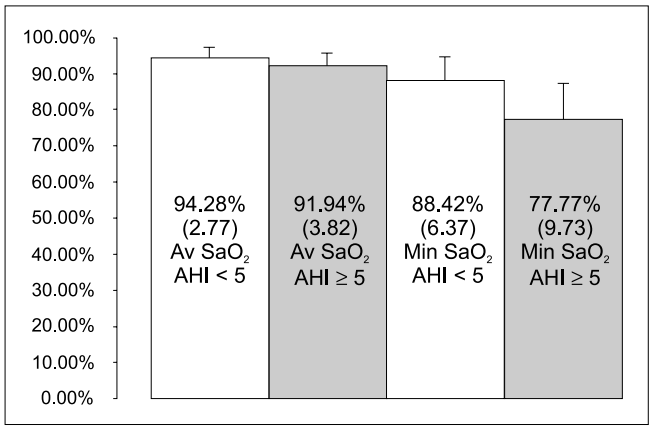

Fig. 2. Average and minimum saturation (SD) in women with AHI < 5 and with AHI ≥ 5

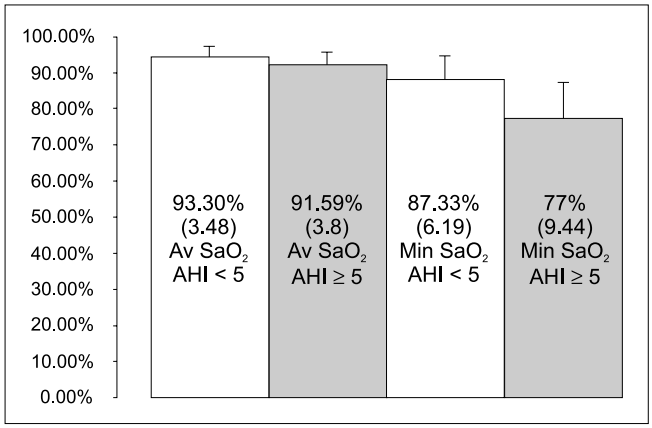

Fig. 3. Average and minimum saturation (SD) in male with AHI < 5 and with AHI ≥ 5

In the average and minimum saturation comparison we found statistically significant differences in average

saturation between the mild and the moderate stage of OSA $p < 0.05$, and between the moderate and the severe OSA stage ($p < 0.0001$). We also noticed differences in minimum saturation between the mild and the moderate stage of OSA ($p < 0.0005$) and the moderate vs the severe stage ($p < 0.0001$).

We also evaluated correlations between AHI and the average and minimum saturation in various stages of OSA severity.

No correlation was found between AHI and average and minimum saturation in mild and moderate stages of OSA severity. However we found negative statistically significant correlation in the severe OSA stage for average and minimum saturation for the whole group in the severe OSA stage and separately for women and male (tab. 6-8; fig. 4-9).

Additionally in the whole OSA group (AHI ≥ 5) we noticed statistically significant correlations between BMI and the average and the minimum saturation (tab. 9; fig. 10, 11). No statistically significant correlations between age and the average and the minimum saturation in AHI ≥ 5 group.

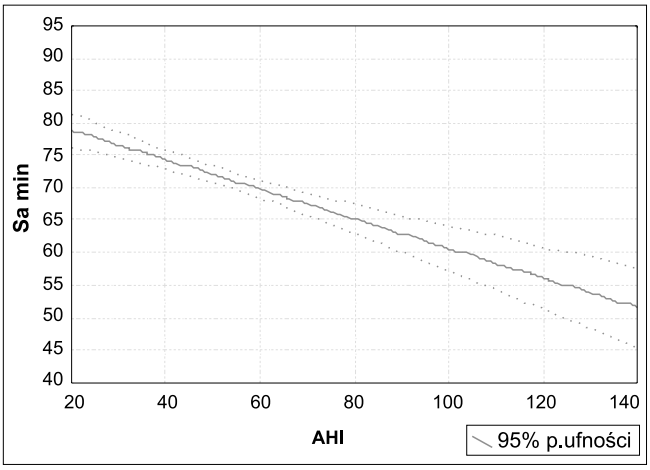

Fig. 5. Correlation AHI vs minimum saturation in severe OSA stage

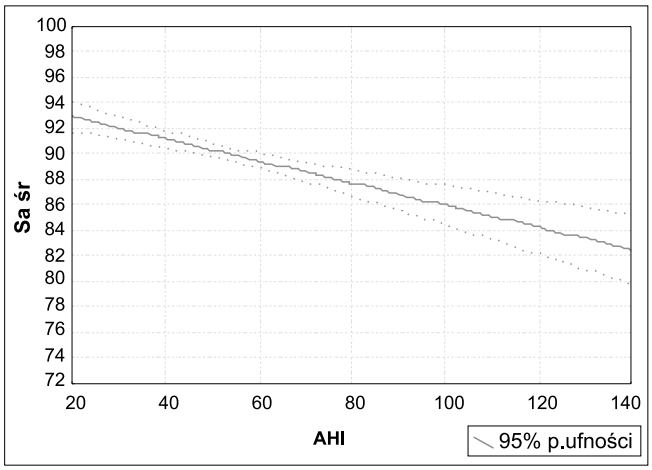

Fig. 4. Correlation AHI vs average saturation in severe OSA

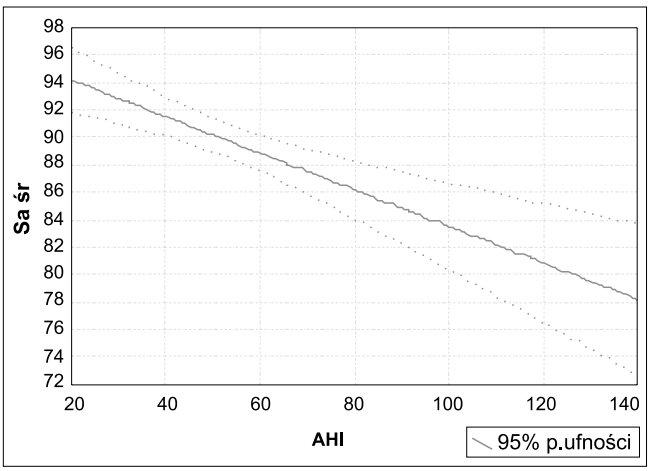

Fig. 6. Correlation AHI vs average saturation in women in severe OSA stage

Table 6. Correlation AHI vs average and minimum saturation in severe OSA stage

Parameters	Average (%)	Standard deviation	n	r	t	p
AHI	52.71	18.05				
Av SaO_2	90.06	4.30	205	-0.3634	-5.5575	< 0.0001
Min SaO_2	71.44	9.95	205	-0.4134	-6.4695	< 0.0001

Table 7. Correlation AHI vs average and minimum saturation in women in severe OSA stage

Parameters	Average (%)	Standard deviation	n	r	t	p
AHI	52.26	20.13				
Av SaO_2	89.87	4.73	42	-0.5669	-4.3524	< 0.0001
Min SaO_2	71.24	10.93	42	-0.5295	-3.9481	< 0.0005

Table 8. Correlation AHI vs average and minimum saturation in male in severe OSA stage

Parameters	Average (%)	Standard deviation	n	r	t	p
AHI	52.82	17.54				
Av SaO_2	90.11	4.19	163	-0.2973	-3.9507	< 0.0002
Min SaO_2	71.50	9.72	163	-0.3758	-5.1457	< 0.0001

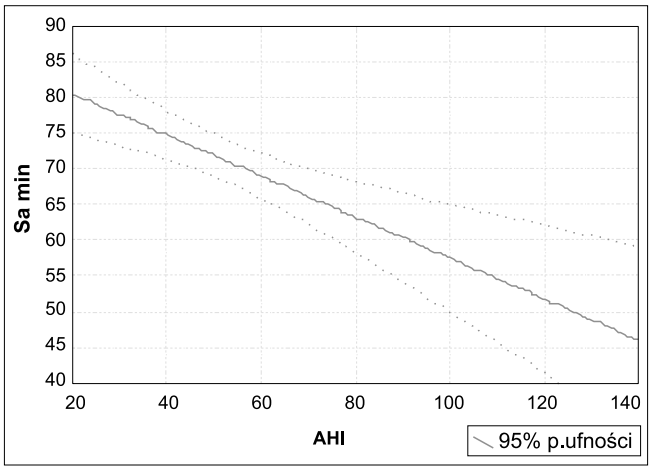

Fig. 7. Correlation AHI vs minimum saturation in women in severe OSA stage

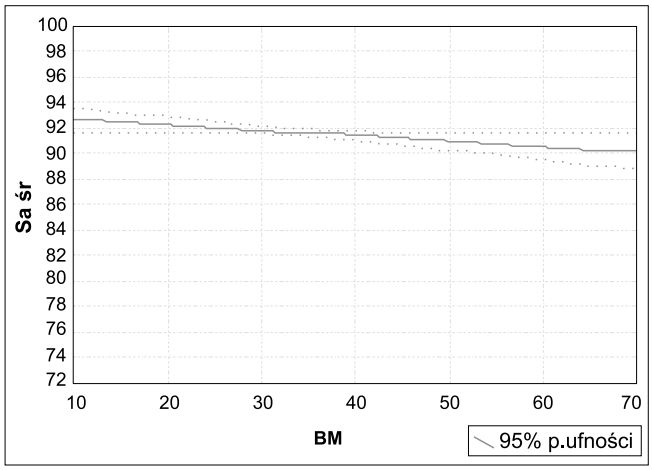

Fig. 10. Correlation BMI vs average saturation in AHI ≥ 5 group

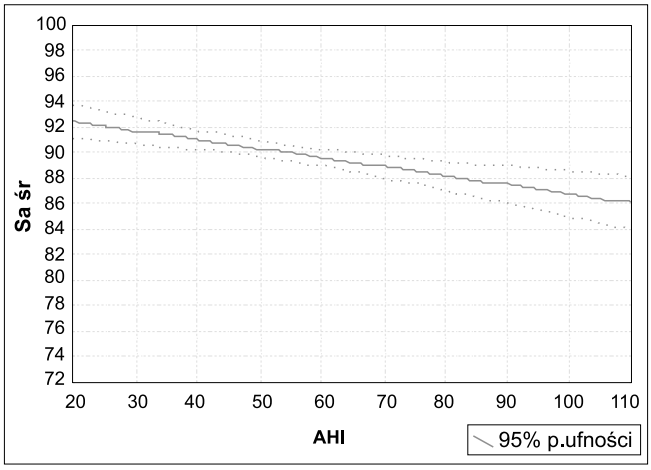

Fig. 8. Correlation AHI vs average saturation in male in severe OSA stage

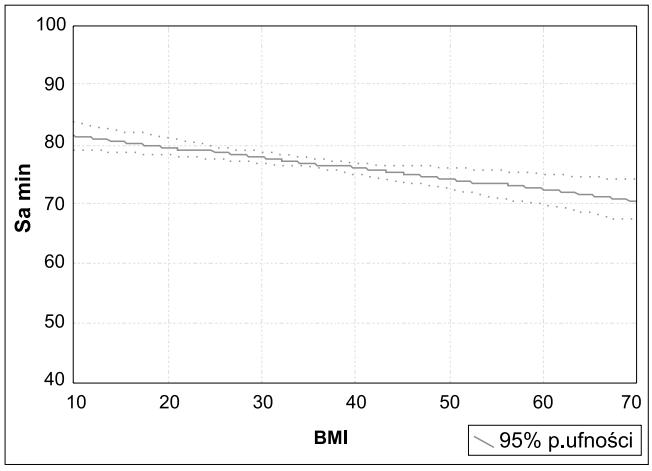

Fig. 11. Correlation BMI vs minimum saturation in AHI ≥ 5 group

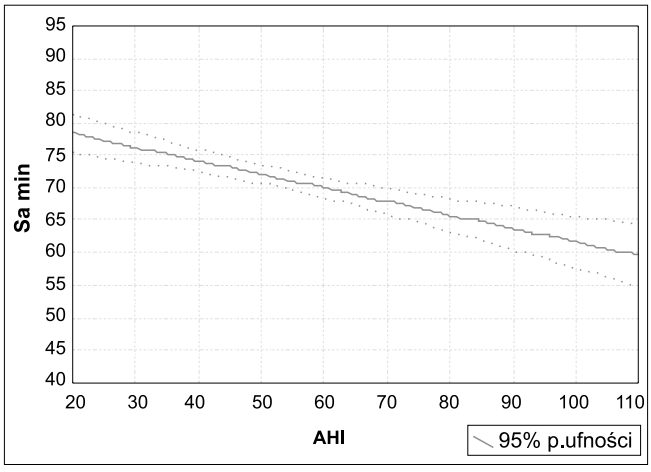

Fig. 9. Correlation AHI vs minimum saturation in male in severe OSA stage

DISCUSSION

Average and minimum oxygen saturations and time with saturation less than 90% saturation during sleep are very important predictors in clinical assessment of OSA patients. Saturation reflects the partial pressure of oxygen in the blood. Typical SaO_2 values for given PaO_2 (pH = normal) is presented in table 10.

Table 10. Typical SaO_2 values for given PaO_2

PaO_2 (mmHg)	SaO_2 (%)
30	60
40	75
60	90

In our study we showed significantly lower values of average and minimum saturations in patients with

Table 9. Correlation BMI vs average and minimum saturation in AHI ≥ 5 group

Parameters	Average (%)	Standard deviation	n	r	t	p
BMI	33.36	8.37				
Av SaO_2	91.69	3.81	557	-0.0931	-2.2038	< 0.05
Min SaO_2	77.21	9.52	557	-0.1572	-3.7497	< 0.0002

AHI ≥ 5 comparing to people with AHI < 5. If we compare results in the AHI ≥ 5 group (OSA-group) in our study to the results of multi-center international project ESADA (The European Sleep Apnea Database) (13) which included 22 sleep medicine centers, in our study we noticed lower average (91.62 (2.29)% vs ESADA 93.2 (4.4)% and minimum saturation 77.21 (9.52)% vs ESADA 81.9 (11.3)%). The differences may be related to anthropometric group characteristic and concomitant clinical factors such as smoking. Unfortunately in our study we have no clinical data to explain the differences. Generally lower values of oxygen saturation at night in OSA patients confirm a tendency for night hypoxia in those patients. We found the lowest values of average and minimum saturations in patients with the severe stage of OSA what can indicate that not only AHI but also night hypoxia are the important OSA severity factors. Also a negative correlation between AHI and the average and the minimum saturation only in the severe stage of OSA may pay particular attention to the severe OSA stage as a complex medical problem.

The night hypoxia is considered as a cause of many OSA symptoms and metabolic complications. For example, one published study showed that in OSA patients who could not use the standard CPAP therapy or surgical treatment of OSA only night oxygen administration by nasal cannula increasing of minimum saturation can improve subjective symptoms of OSA. Decreased ESS (Epworth Sleepiness Scale) score was noticed. However Apnea-Hypopnea Index did not significantly change (14). Considering OSA symptoms morning headache is the next which can be considered related to low minimum and average saturation at night, but published data questioned the relation between morning headache and night hypoxia (15). From the metabolic point of view the role of night hypoxia in OSA has to be also considered as an important factor. In published data independent association of minimum night saturation with IL-6 (Interleukin-6) and CRP level was found (16). In another study, AHI and mean desaturation (sleep time spent below oxyhemoglobin saturation of 90%) was perceived as a significant independent predictor for elevated sVCAM-1 and leptin (17).

Medical data highlight not only the role of nocturnal hypoxia but also the role of intermittent hypoxia on the metabolism of human body. Intermittent hypoxia has a broad impact on the metabolism of the body, on cardiovascular complications (2). It has been documented that recurrent hypoxia stimulates the inflammatory factors, chemokines, adhesion molecules that are involved in the damage of endothelial cells (18) and have atherosclerotic action (19). Numerous studies have confirmed elevated levels of adhesion molecules in the serum of patients with OSA, and their relationship with hypoxia (20, 21), indicating their involvement in the pathogenesis of cardiovascular OSA. It is also known that hypoxemia is responsible for the rise in blood pressure, increased myocardial contractility and cardiac output, and tachycardia. This leads eventually to an increased demand for oxygen by the heart muscle (22). Because of the important role of nocturnal saturation in OSA patients as a predictor of OSA severity, its correlation with severity of disease and many metabolic consequences, its exponents such as the average saturation, the minimum saturation and also oxygen desaturation index and sleep time with saturation below 90% should be used as an object of medical research as well as AHI.

We found differences in the Av SaO_2 and Min SaO_2 among the non-OSA and the OSA patients, and between the different stages of OSA advancement. In more advanced OSA we observed a lower Av SaO_2 and Min SaO_2 which is additional to AHI hint to apply the treatment and prevent complications associated with hypoxia.

For the severe OSA stage we noticed a statistically significant negative correlation between average and minimum oxygen saturations and AHI. We observed a stronger negative correlation for women with severe OSA.

According to obesity as a main risk factor of OSA we analyzed a correlation between BMI and both the average and the minimum saturation in AHI ≥ 5 group, we found statistically significant negative correlations for BMI vs the average saturation ($r = -0.093$; $p < 0.05$) and BMI vs the minimum saturation ($r = -0.16$; $p < 0.0002$).

CONCLUSIONS

We concluded in more advanced OSA lower Av SaO_2 and Min SaO_2 were observed which is additional to AHI hint to apply the treatment and prevent complications associated with hypoxia.

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