Original article

The Effect of Continuous Positive Airway Pressure on Middle Ear Pressure

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Abstract

Aim of the study: The study investigated the effects of continuous positive airway pressure (CPAP) on middle ear pressure.

Methods: Forty-two patients with obstructive sleep apnea (OSA) were assigned to the study group. The patients underwent standard tympanometry before starting CPAP therapy and six months after regular CPAP therapy.

Results: The average pressure range of the CPAP device (cm H2O) was 4,80 – 13,50. Middle ear pressure (MEP) was between -146,00 and 64,00 daPa before therapy and between -103,00 and 40,00 daPa after treatment. The results showed that the subjects experienced an increase in middle ear pressure after the CPAP therapy.

Conclusion: This study demonstrated that the appropriate use of CPAP therapy leads to a statistically significant increase in pressure in the middle ear.

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Introduction

Obstructive sleep apnea is a breathing disorder characterized by repeated episodes of partial or complete obstruction of the upper airways during sleep lasting at least 10 seconds, with consequent partial or complete cessation of breathing. (1,2). It is estimated that one-seventh of the adult population worldwide suffers from this disorder (3). A recent study found that 936 million adults worldwide aged 30 to 69 have OSA and 425 million adults aged 30 to 69 have moderate to severe OSA (5). According to the Wisconsin Sleep Cohort Study, 17.4% of women and 33.9% of men in the United States aged 30 to 70 have at least mild obstructive sleep apnea (1). The diagnosis is made by polysomnography, a method that represents the gold standard in diagnosing the disease. Continuous positive airway pressure (CPAP) is the first and most common choice of conservative therapy in patients with OSA (1). The principle of action is to prevent the closure and narrowing of the structures of the upper respiratory tract during sleep by applying positive pressure. CPAP involves a mask that covers the nose and/or mouth, a tube that connects the mask to the monitor, and a monitor that blows air into the tube. A pressure ranging from 4 to 20 cm H2O is applied, depending on the individual needs (5). Many patients have difficulties adapting to the use of the device, and due to phenomena such as allergic rhinitis, dryness of the mucous membrane of the upper respiratory tract, dysfunction of the Eustachian tube, as well as the noise of the device, they give up treatment.

The middle ear communicates with the nasal part of the pharynx through the Eustachian tube. Inside the middle ear, there is air under pressure that should be equal to atmospheric pressure. It is through the Eustachian tube that the pressure is equalized and maintained in the middle ear (6). Given that continuous positive pressure in the airways prevents the collapse of the pharyngeal musculature, this study aimed to examine the effect of such therapy on the middle ear, which communicates with the pharynx via the Eustachian tube. We hypothesize that middle ear pressure will have a directly proportional relationship to CPAP pressure in patients not only during therapy but also after the application of CPAP therapy. Earlier studies mainly examined the pressure in the middle ear during CPAP therapy. In this study, we measured the pressure in the middle ear in patients treated with CPAP therapy who did not wear CPAP during tympanometry.

Tympanometry (Ty) is a method that tests the compliance of the eardrum and the auditory chain. In a normal healthy ear, middle ear pressure is equal on both sides of the eardrum and then there is the lowest resistance to sound transmission and the compliance is the highest. In a normal, healthy ear, this pressure ranges from - 150 to + 50 deka Pascals (daPa), and compliance is from 0.18 to 1.8 milliliters (mL). A probe with three channels is placed in the patient's ear canal: a speaker, a microphone, and a channel that changes pressure. This is an objective method, but the movement during the examination and swallowing can affect the result. The result of the test is a curve that shows how many sounds released into the external ear canal bounced off the eardrum and returned to the microphone. There are three basic types of curves: Type A curve with pressure ranging from - 150 to + 50 daPa which is a regular finding; type C with a shift to negative at ≥ - 150 daPa in which, due to negative pressure, usually due to dysfunction of the Eustachian tube, the mobility of the chain of auditory ossicles is lessened. Type B curve usually has the appearance of a flat line, without a characteristic peak, mostly in favor of the rigidity of the chain of auditory ossicles or the presence of fluid in the middle ear (7).

With this research, we wanted to investigate the additional effects of CPAP therapy on other organ systems (in this example, the middle ear) with the aim of better understanding possible side effects that would lead to a decrease in cooperation in treatment.

Methods

The study was conducted in the Clinical Hospital Center Osijek in Croatia, where 42 adults with a new diagnosis of moderate to severe OSA (defined as an apnea-hypopnea index; AHI ≥15/h) were prospectively followed. The study was approved by the Ethics Committee of the

Clinical Hospital Center Osijek (R1/6414/2021, Osijek 2021) and Faculty of Medicine Osijek (No. 602-04/21-08/07; 2158-61-07-21-149, Osijek, 2021) and all participants signed an informed consent. All participants received CPAP therapy and agreed to participate in a 6-month follow-up. The inclusion criteria were age between 29 and 69, participants with normal hearing threshold and sensorineural hearing impairment, and participants with type A curves. The middle ear pressure was evaluated after 6 months of CPAP therapy. The exclusion criteria were middle ear disease, non-cooperation in the application of CPAP therapy (good co-operation is defined by the use of CPAP for 4 hours of sleep during the night, at least 70% of the night (8,9) and withdrawal from further monitoring at one's request.

Statistical analysis

Categorical data are presented with absolute and relative frequencies. Numerical variables are described by arithmetic mean, standard deviation, median, range, and interquartile range. A Shapiro-Wilk test was conducted to determine whether the differences between the two related groups are normally distributed. Since the assumption of normality was met and the sample size was adequate, a paired-samples t-test was used to determine if there was a significant difference in the middle ear pressure between the pre- and post-therapy results. Statistical significance was set at the level of P<0,05. Statistical analysis was performed using IBM SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.) and MedCalc Statistical Software version 22.023 (MedCalc Software Ltd, Ostend, Belgium; https: //www.medcalc.org; 2024).

Results

The study included 42 patients with OSA, a total of 84 ears. The age of the participants ranged between 29 and 69; the mean age was 52,43 years (Table 1). Table 1 also shows descriptive statistics of AHI in patients with OSA and average pressure of CPAP.

Table 2 shows the distribution of patients according to the degree of apnea to those with moderate and those with severe apnea. In the study, 11 subjects had moderate OSA, and 31 had severe OSA.

Table 1. Descriptive statistics of age, AHI and average pressure of CPAP

Descriptive statistics	OSA group Age	OSA group AHI	OSA group after 6 months of therapy Average pressure of CPAP (cm H_2O)
N	42	42	42
Mean (SD)	52,43 (10,73)	47,50 (23,30)	7,54 (1,64)
Range	29,00 – 69,00	18,20 – 99,70	4,80 – 13,50

N – Number; SD – Standard deviation: OSA – Obstructive sleep apnea; AHI – Apnea-Hypopnea Index; CPAP – Continuous positive airway pressure

Table 2. Distribution of patients according to the degree of apnea

Variable		OSA group
AHI	Moderate OSA (15 – 30)	11 (26,2 %)
	Severe OSA (> 30)	31 (73,8 %)
Total		42 (100,0 %)

OSA – Obstructive sleep apnea; AHI – Apnea-Hypopnea Index

After 6 months, all subjects had their cooperation checked by a neurologist at a follow-up examination and the pressure value of the CPAP device was read from the SD card. The average pressure range of the CPAP device (cm H2O) was 4,80 – 13,50. All subjects had well-titrated CPAP devices (Table 1).

After the follow-up, they all underwent a control otoscopic examination and repeated tympanometry. Of the total number of subjects, none had a subjective feeling of fullness in the ear during or after CPAP therapy.

Middle ear pressure (MEP) was between -146,00 and 64,00 daPa before therapy and between -103,00 and 40,00 daPa after treatment. The results showed that the subjects experienced an increase in middle ear pressure after the CPAP therapy and that the difference in pressure before and after the therapy can be considered statistically significant (Table 3).

Table 3. Results of tympanometry analysis

Variable	Descriptive statistics and results of testing	OSA group before CPAP therapy		OSA group after 6 months of CPAP therapy
Middle ear pressure (daPa)	N	84		84
	Mean (SD)	-19,90 (36,57)		-0,58 (21,78)
	Range	-146,00 – 64,00		-103,00 – 40,00
	Difference		-19,32	
	95% Confidence Interval of the Difference	Lower: -25,04		Upper: -13,61
	P-value		*P* < 0,001*	

** Paired-sample t-test*

Discussion

It has been recorded in the literature that during CPAP therapy, the pressure in the middle ear can increase. What the literature does not tell us is how much this pressure is elevated, whether the values are still within the reference intervals, and whether this affects the subjective experience of the patient. In a study by authors Sivri et al. on 78 patients with moderate and severe OSA who were treated with CPAP therapy, an increase in middle ear pressure was recorded after 6 months of therapy, but tympanometrically it was still a regular type A curve (10). Ma et al analyzed the results of seven articles with a total of 664 subjects using a CPAP device. They demonstrated that short-term use of CPAP is associated with a transient increase in middle ear pressure in adults and that long-term use of CPAP could produce beneficial changes in the middle ear, particularly in patients with OSA and Eustachian tube dysfunction (11). An increase in pressure in the middle ear after CPAP treatment was also shown by Cheung et al (12). Mc Cormick et al presented a case of a patient in whom middle ear barotrauma occurred due to inadequate self-titration of the CPAP device (13). In this study, all subjects had an adequate titration of the CPAP device with a median of 7.10 cm H2O and a range of 4.8 to 13.5 cm H2O. During monitoring, no deviation from normal values of pressure in the middle ear was noted. A significant increase in pressure in the middle ear after CPAP treatment was recorded, which corresponds to data from the literature, but none of the subjects felt subjective complaints such as a feeling of fullness or pressure in the ears.

The limitations of this study are the small number of respondents and the fact that the research was conducted in only one center.

In conclusion, this study demonstrated that the appropriate use of CPAP therapy leads to a statistically significant increase in pressure in the middle ear during 6 months. Increased pressure in the middle ear does not cause subjective disturbances in patients who are on CPAP therapy, and it is not one of the reasons for abandoning treatment

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Učinak kontinuiranoga pozitivnog tlakana tlak u srednjem uhu

Sažetak

Cilj studije: Studija je ispitivala učinke kontinuiranog pozitivnog tlaka u dišnim putovima (CPAP) na tlak u srednjem uhu.

Metode: Četrdeset i dva pacijenta s opstruktivnom apnejom u snu (OSA) uključena su u istraživačku skupinu. Pacijenti su podvrgnuti standardnoj timpanometriji prije početka CPAP terapije i šest mjeseci nakon redovite CPAP terapije**.**

Rezultati: Prosječni raspon tlaka CPAP uređaja (cm H_2O) bio je od 4,80 do 13,50. Tlak u srednjem uhu (MEP) kretao se između -146,00 i 64,00 daPa prije terapije te između -103,00 i 40,00 daPa nakon terapije. Rezultati su pokazali da su ispitanici nakon CPAP terapije imali povećanje tlaka u srednjem uhu.

Zaključak: Ova studija pokazala je da odgovarajuća primjena CPAP terapije dovodi do statistički značajnog povećanja tlaka u srednjem uhu.