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ORIGINAL STUDY

The influence of body position on the nasal ventilation in healthy subjects. A study by 4-phase-rhinomanometry

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ABSTRACT

BACKGROUND. The influence of nasal breathing on the quality of sleep is a well-known clinical phenomenon, which gets an increasing interest in sleep medicine. There are only few investigations showing how breathing changes during posture change. 4-Phase-Rhinomanometry (4PR) is a useful method to objectively measure nose breathing changes during different body postures.

OBJECTIVE. This confirmatory study determines variation ranges of nasal resistance following changing of body position from sitting to supine and 30-degree elevation in healthy young persons.

MATERIAL AND METHODS. 44 healthy volunteers, without a history of nasal blockage or sleep-related breathing disorders, have been investigated by 4PR. Three subsequent measurements have been carried out: A. after 15 minutes in sitting position; B. after 15 minutes in supine position; C. after 15 minutes in supine position with 30° head elevation. The subjective nasal obstruction was evaluated by a four-point Likert scale.

RESULTS. The T-tests between the three groups showed high significant differences in the nasal resistance after changing to the supine position. The differences for the Logarithmic Vertex and Logarithmic Effective Resistances were highly significant in inspiration as well as in expiration. Also, the difference between the results in sitting and 30° elevated position was significant in both measurement modes.

CONCLUSION. Confirmed dependency of the nasal resistance on posture leads to the conclusion that objective measurement of the nasal resistance by 4PR should be included in the routine diagnostic work in sleep medicine.

KEYWORDS: nasal ventilation, 4-phase-rhinomanometry, supine, sleep medicine, nasal resistance

INTRODUCTION

The influence of nasal breathing on the quality of sleep is a well-known clinical phenomenon, which gets an increasing interest in sleep medicine. Normal nasal ventilation is the key for a successful CPAP-treatment. In other cases, snoring may be cured by nasal surgery with or without other measures[1-3]. Increased nasal resistance has been shown to negatively affect the quality of sleep and therefore the quality of life[4]. In 2010, the International Standardization Committee of Upper Airway Assessment introduced 4-Phase-Rhinomanometry (4PR) as one standard method for testing nasal resistance. Rhinomanometry measures nasal resistance to respiratory airflow through a dynamic procedure, by calculating nasal airway resistance in inspiration and expiration at different pressures. In a recent paper, Toh, Lin and Guilleminault[4] demonstrated that 4PR developed by Vogt et al. is a valuable tool to evaluate the role of nasal breathing in somnological patients[5].

It was proposed to introduce 4PR as a routine investigation in sleep medicine, but more research data are needed to confirm that it is effective. There are only few investigations showing how breathing changes during posture change. 4PR is a useful method to objectively measure nose breathing changes during different body postures[5]. Despite nasal resistance being an important factor when evaluating patients, objective assessment using rhinomanometry is frequently not performed.

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This confirmatory study determines variation ranges of nasal resistance following changing of body position from sitting to supine and 30-degree elevation in healthy young persons.

MATERIAL AND METHODS

44 healthy volunteers (16 male and 28 female), aged between 14 and 27 years, without a history of nasal blockage or sleep-related breathing disorders, have been investigated by 4PR. All adult volunteers as well as the parents of those between 14 and 18 years of age signed the informed consent for the study.

The subjective nasal obstruction perceived by the subjects was evaluated by a four-point Likert scale (from 1¼ no problem breathing through the nose, 2¼ mild problem breathing through the nose, 3¼ problem breathing through the nose, and 4¼ impossible to breathe through the nose)[4]. The "4RHINO" rhinomanometer (Rhinolab GmbH, Freiburg/Germany) with the software 4.31 was used. The investigations have been carried out as Active Anterior Rhinomanometry for the determination of the resistance of the right and left nostril (Figure 1). The pressure tube was fixed by tape (Microfoam®, 3M) to preserve the elastic properties of the nasal entrance.

Figure 1 Rhinomanometer "4RHINO" (Rhinolab GmbH, Freiburg/Germany)

During the investigation, 3 subsequent measurements have been carried out:

A: Measurement of right and left nasal side breathing after 15 minutes in sitting position in rest and room temperature;

B: Measurement after 15 minutes in supine position in rest and room temperature;

C: Measurement after 15 minutes in supine position with 30° head elevation in rest and room temperature.

The measurement time was 15 seconds per nostril with minimum 3-5 breathes in each body position.

In accordance with the recommendations of the International Standardization Committee of the International Rhinologic Society (ISCOANA) and to provide the comparison with previous data, the flow at 150Pa during the 4 phases of the breathing cycle was documented. Beside it, other important values typical for 4-phase-rhinomanometry, characterizing the entire energy of the nasal air stream, were considered: the Effective Resistance (Reff) (in inspiration (ReffIn), expiration (ReffEx) and the entire breath (Reff)) and Vertex Resistance (VR) (in inspiration (VRin) and expiration (VRex)), which is defined as the linear quotient between differential pressure and flow at the highest flow during inspiration or inspiration in a regular breath. Because it could be repeatedly shown, that logarithmic transformation leads to a normal statistical distribution; this transformation as provided by the 4RHINO-program was included into the statistical evaluation below. The total resistance was calculated as usual for the calculation of electric parallel resistors:

$$Value_{Total} = \frac{Value_{right} * Value_{left}}{Value_{right} + Value_{left}}$$

The data have been exported to Microsoft Excel for statistical data processing. Height, weight and BMI (Body Mass Index) have been determined as anthropometric measurements.

RESULTS

The results of the descriptive statistics are summarized in Tables 1 - 4. The groups A, B and C have been compared by T-tests for depending samples.

Respective graphs are depicted in Figure 2 and 3 for the unilateral measurements and Figure 4 and 5 for the calculated Total Resistance. The T-tests between the groups are showing high significant differences (Table 5), i.e. a remarkable increase of the nasal resistance after changing to the supine position. The differences for the Logarithmic Vertex and Logarithmic Effective Resistances are highly significant in inspiration as well as in expiration. The inspiratory resistance is generally higher than the expiratory resistance. Also, the difference between the results in sitting and 30° elevated position is highly significant in both measurement modes. The differences between groups B and C, i.e. supine and 30° elevated position, show the same tendency, but are not significant at a level of 5%. The numeric difference is even lower after calculating the Total Resistance (bilateral resistance). This result is caused by a big variance of the individual differences due to the reaction of changing the body position. As an example, Figure 6 shows the individual values of 22 measurements compared to each other to demonstrate the width of possible variations.

Table 1
Anthropometric Data

	Weight	Height	BMI	Age
Mean	**65.5**	**1.7**	**21.8**	**23.5**
Median	65	1.72	21.943	23
Standard Deviation	11.64	0.11	2.198	2.959
Minimum	35	1.35	17.6	14
Maximum	93	1.96	26.6	30
N	88	88	88	88

Table 2
Active Anterior Rhinomanometry (ISCOANA)

	A150_Pa_in1	A150_Pa_in2	A150_Pa_e1	A150_Pa_e2
Mean	**260.2**	**233.6**	**-243.5**	**-265.5**
Median	248	220	-220	-238.5
Standard Deviation	139.3	137.1	135.4	144.1
Minimum	56	31	-754	-786
Maximum	877	921	-68	-60
N	86	86	77	76
	B150_Pa_in1	**B150_Pa_in2**	**B150_Pa_e1**	**B150_Pa_e2**
Mean	**195.8**	**176.0**	**-171.9**	**-185.7**
Median	198.5	170.5	-148	-177
Standard Deviation	112.8	105.9	102.6	104.5
Minimum	-23	-18	-505	-542
Maximum	592	579	-39	-39
N	84	84	78	78
	C150_Pa_in1	**C150_Pa_in2**	**C150_Pa_e1**	**C150_Pa_e2**
Mean	**204.8**	**177.5**	**-182.6**	**-199.9**
Median	189	169	-156.5	-183
Standard Deviation	95.5	93.3	110.6	112.1
Minimum	26	16	-642	-653
Maximum	478	473	-41	-41
N	81	81	76	75

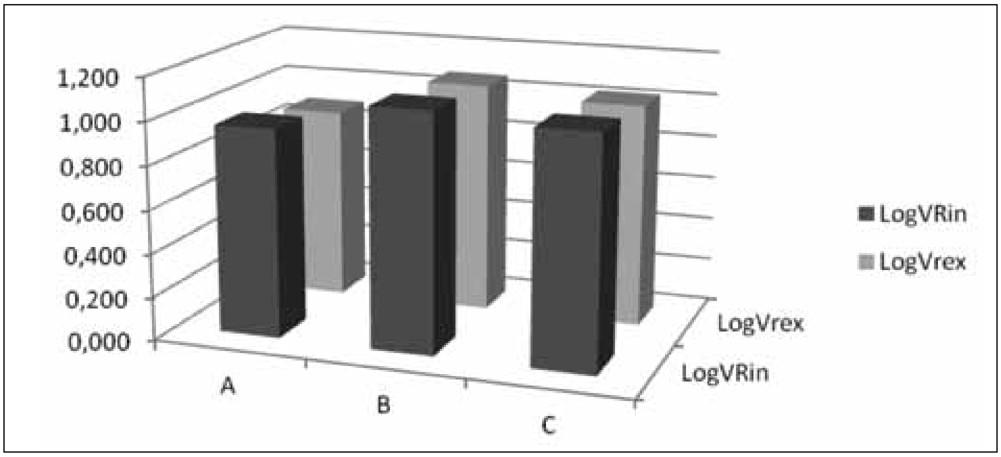


Figure 2 Position depending differences in Logarithmic Vertex Resistance – unilateral measurements

Table 3
Active Anterior Rhinomanometry (4PR-values)

	ALogVRin	ALogVRex	ALogReffIn	ALogReffEx	ALogReff
Mean	**0.960**	**0.891**	**1.069**	**0.866**	**0.918**
Median	0.956	0.911	0.936	0.890	0.920
Standard Deviation	0.270	0.287	0.736	0.289	0.268
Minimum	0.104	0.311	0.076	0.290	0.204
Maximum	1.551	1.607	4.288	1.590	1.551
N	88	88	88	88	88
Active Anterior Rhinomanometry	**BLogVRin**	**BLogVRex**	**BLogReffIn**	**BLogReffEx**	**BLogReff**
Mean	**1.095**	**1.068**	**1.071**	**1.044**	**1.069**
Median	1.041	1.025	1.021	0.995	1.025
Standard Deviation	0.299	0.341	0.306	0.349	0.309
Minimum	0.451	0.195	0.417	0.176	0.464
Maximum	1.652	1.658	1.633	1.657	1.624
N	88	88	88	88	88
Active Anterior Rhinomanometry	**CLogVRin**	**CLogVRex**	**CLogReffIn**	**CLogReffEx**	**CLogReff**
Mean	**1.057**	**1.024**	**1.034**	**0.999**	**1.028**
Median	1.044	1.015	1.019	0.983	1.003
Standard Deviation	0.302	0.327	0.306	0.330	0.304
Minimum	0.216	0.240	0.190	0.207	0.283
Maximum	1.711	1.683	1.679	1.671	1.676
N	88	88	88	88	88

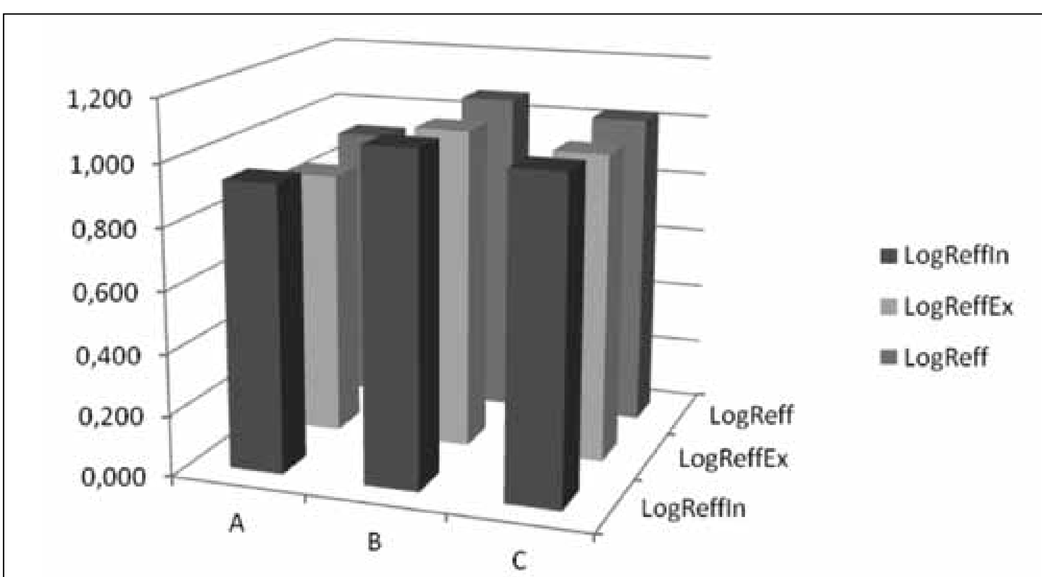


Figure 3 Position depending differences in Logarithmic Effective Resistance

Table 4
Total Resistance, calculated

	ALogVRinTot	ALogVRexTot	ALogReffinTot	AlogReffExTot	AlogReffTot
Mean	**0.625**	**0.551**	**0.610**	**0.525**	**0.582**
Median	0.630	0.571	0.606	0.546	0.602
Standard Deviation	0.213	0.216	0.227	0.217	0.204
Minimum	-0.103	0.046	-0.143	0.033	-0.037
Maximum	1.086	0.980	1.057	0.967	1.025
N	44	44	44	44	44
Total Resistance, calculated	**BlogVRinTot**	**BlogVRexTot**	**BlogReffInTot**	**BlogReffExTot**	**BlogReffTot**
Mean	**0.745**	**0.710**	**0.718**	**0.683**	**0.715**
Median	0.737	0.725	0.714	0.691	0.713
Standard Deviation	0.206	0.250	0.211	0.254	0.212
Minimum	0.342	0.082	0.304	0.045	0.375
Maximum	1.124	1.129	1.100	1.099	1.100
N	44	44	44	44	44
Total Resistance, calculated	**ClogVrinTot**	**ClogVRexTot**	**ClogReffInTot**	**ClogReffExTot**	**ClogReffTot**
Mean	**0.704**	**0.668**	**0.681**	**0.642**	**0.673**
Median	0.703	0.661	0.671	0.638	0.647
Standard Deviation	0.210	0.234	0.216	0.237	0.205
Minimum	0.170	0.104	0.164	0.074	0.236
Maximum	1.144	1.203	1.117	1.137	1.119
N	44	44	44	44	44

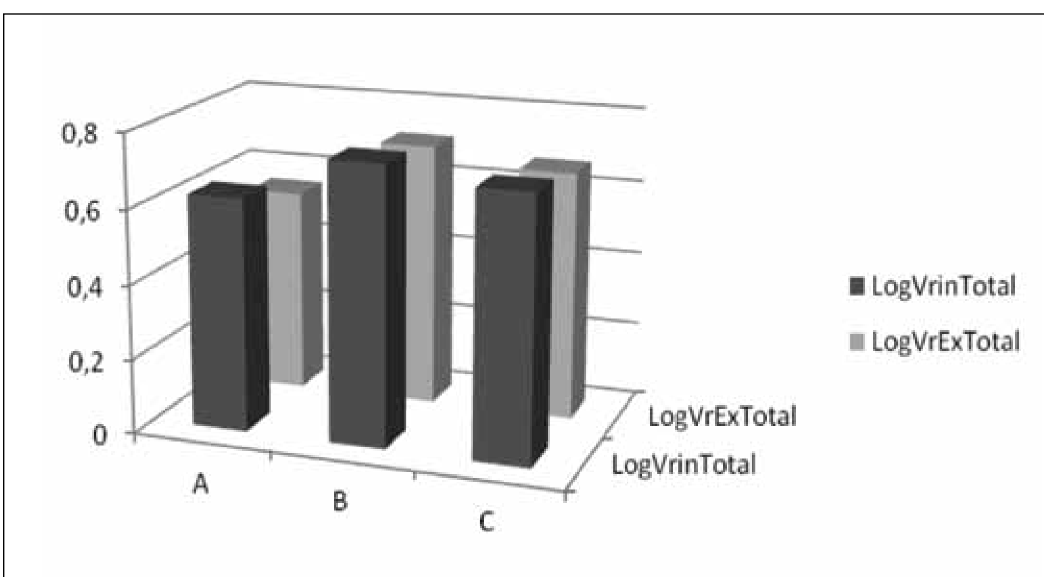


Figure 4 Position depending differences of Logarithmic Total Vertex Resistance

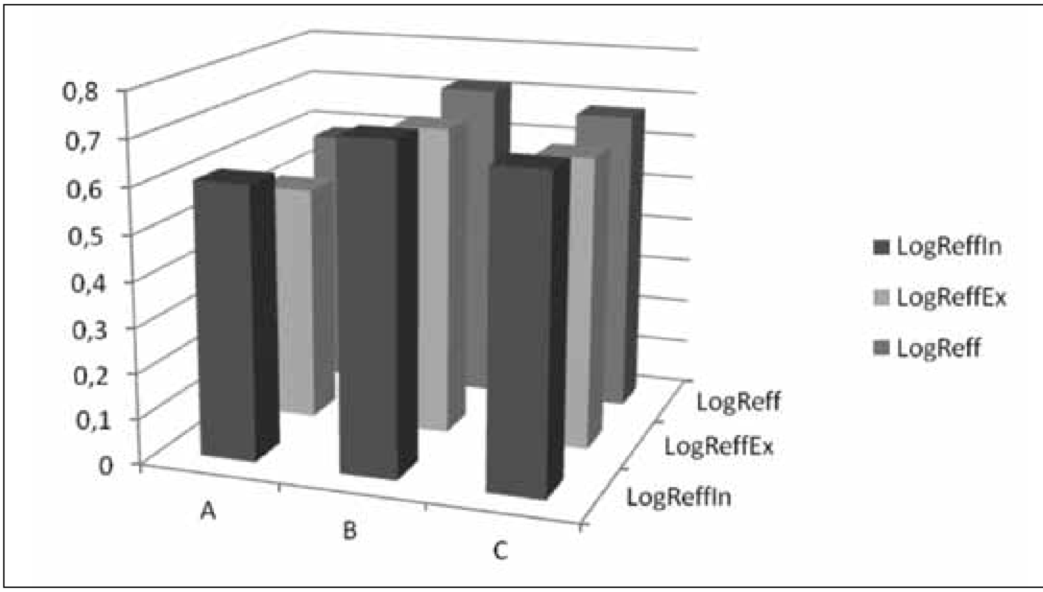
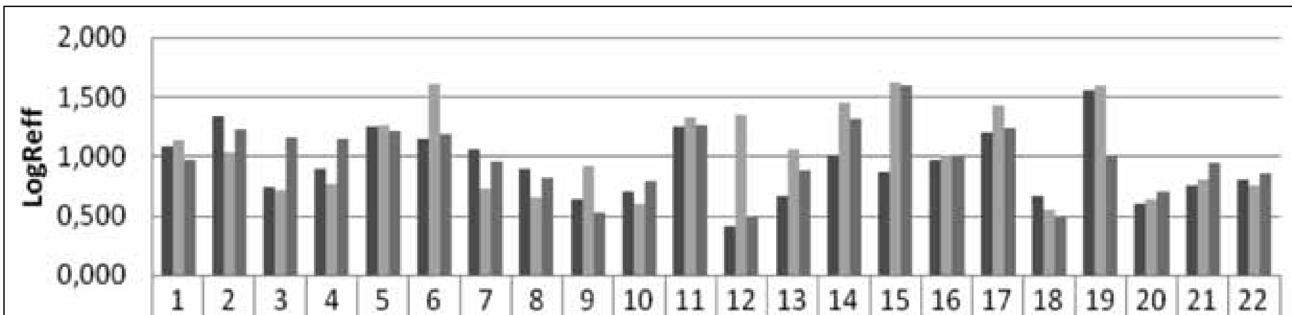


Figure 5 Position depending differences of Total Effective Resistance



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	1,0	1,3	0,7	0,8	1,2	1,1	1,0	0,8	0,6	0,7	1,2	0,4	0,6	1,0	0,8	0,9	1,1	0,6	1,5	0,6	0,7	0,8
B	1,1	1,0	0,7	0,7	1,2	1,6	0,7	0,6	0,9	0,5	1,3	1,3	1,0	1,4	1,6	1,0	1,4	0,5	1,5	0,6	0,8	0,7
C	0,9	1,2	1,1	1,1	1,2	1,1	0,9	0,8	0,5	0,7	1,2	0,4	0,8	1,3	1,5	0,9	1,2	0,5	0,9	0,7	0,9	0,8

Figure 6 Individual differences in nasal resistance after changing the body position. (A sitting, B supine, C 30° elevation)

Table 5
Statiscal analysis results

Correlations

		A	B	C
A	Pearson Correlation	1	,325*	,423**
	Sig. (2-tailed)	,	,032	,044
	N	44	44	44
B	Pearson Correlation	,325*	,1	,672**
	Sig. (2-tailed)	,032	,	,000
	N	44	44	44
C	Pearson Correlation	,423**	,672**	,1
	Sig. (2-tailed)	,044	,000	,
	N	44	44	44

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

DISCUSSIONS

In our study we have found that there is an increase of nasal resistance after the transition from sitting to the supine position measured with 4PR. We investigated healthy young people without complains about breathing through the nose in sitting, supine position or with 30-degree head elevation during supine position. Changing of resistance during measurements means that body position during sleep could affect nose breathing resistance and 4PR is an appropriate device to measure these changes. So, before any surgical or other interventions, patients should be checked for these changes to access better diagnostics and therapy outcome.

The statistical results of our study confirm previous observations, as recently reported by Toh et al., that 4PR is a test which can be easily performed to characterize nasal resistance and determine changes in resistance after changing body position. In their study, Toh et al. found that sleep apnea patients who did not demonstrate a decrease in nasal resistance with inclined position were more likely to be noncompliant with nasal CPAP. These measurements could help to objectively identify patients who might have trouble tolerating nasal CPAP and prove that 4PR is useful for nose breathing data recording before sleep apnea therapy initiation. They conclude that there is a decrease in nasal resistance during 30-degree head elevation compared to supine position[2]. In our study, we found that nasal resistance during 30-degree head elevation is variable in different persons. That could demonstrate that for sleep apnea patients it is easier to breathe with 30-degree head elevation, but for healthy subjects it is variable.

The effect of position change from the supine to the erect position on nasal resistance had been previously studied. In Virkkula et al. research, supine position was associated with increased total nasal resistance compared to the seated position[6]. De Vito et al. also showed pathologic nasal resistance in 16 out of 36 subjects with sleep apnea in the supine position compared to the seated position[7]. Studies in the literature indicate that changing from the sitting to supine posture will generally lead to an increase in nasal resistance even in normal subjects. Our study had 44 healthy young subjects whose nasal resistance increased with positional change from sitting to supine and 30-degree head elevation. Skinner et al., in their investigation of 14 subjects, showed similar results in the elevated posture (60-degree elevation during sleep); 11 subjects achieved reduction in apnea-hypopnea index (AHI). They concluded that sleeping at an angled position provides a satisfactory outcome in a limited number of patients. They could not identify any relationship between baseline AHI or Body Mass Index (BMI) and the success of sleeping at an angle[8]. Further studies with larger patient numbers are wanted to investigate this topic.

There are certain limitations in our study. First, the result might have been different if we have had a larger number of patients and more defined groups that could be separated by gender, age, medical history. We had only young people – 14 to 27 years old; it would be useful to look at other age groups to get more objective results. However, a previous study in adults has shown that there is no correlation between total nasal resistance and age[9]. Secondly, this study was performed in the Caucasian population only. There are no data if ethnicity makes a difference to the result. Third, because of the difference in the used technology, comparison between our study and previous studies may have limitations, and indicates the need to perform more studies using the 4PR. It is important to have new studies looking at nasal resistance in the supine position, as it relates more to the sleeping posture and sleeping disorders disturb patients more often. The fourth limitation could be the four-point Likert scale usage to evaluate subjective nasal obstruction; objective measurements could give more precise results. If a person evaluates nose breathing by himself and has a permanent obstruction, he might feel good nose breathing despite the pathology. In the future, for studies like this, we would suggest a close collaboration with the otorhinolaryngologist and, before measurement with 4PR in different body positions, taking one measurement with nasal decongestant. Fifth - our measurements for nasal resistance were performed between 11th and 16th hour, but previous studies have shown that there are diurnal variations in nasal resistance with worsening at night[10-12]. Diurnal cycles can be different for each person, which could explain measurement variations in our study. Performing similar tests with 4PR during the day and night to see the difference could be interesting. In our study, people were awake during the test, but nose adaptation to body position change can be different during sleep. So, it would be more useful to perform those measurements during sleep if we are thinking about CPAP therapy and nose breathing in sleep disorders. Sixth, in our study, each measurement was performed after being 15 minutes in the same body position, but it could be interesting to look after 30 and 60 minutes during sleep in the same position because nose adapts and, if we should decide about CPAP treatment according to measurement, that could be important.

Data about objectively measured nasal resistance and different conditions that could affect it are still lacking. The relationship between postural change and nasal resistance has been studied before, but the number of patients in those studies was small and methodology differs, so it is hard to compare investigations. Confirmatory studies are still needed to evaluate how body posture affects nasal resistance. The relationship between age, postural change and nasal resistance has not been previously studied and is topic for further investigations.

Sleep disorders that could be caused by nasal resistance changes during supine position are an important topic because the number of patients with sleep apnea and different sleep disturbances is rising. In our data, confirmed dependency of the nasal resistance on posture leads to the conclusion that objective measurement of the nasal resistance by 4PR should be included into the diagnostic routine. The information of 4PR is extremely important for the decision about conservative or surgical treatment of the nose for patients with sleep-disordered breathing. The simple and cost-effective diagnostic method enhances the entire information and is effective in minimizing the risk for the patients and the unnecessary costs for ineffective CPAP machines and surgical manipulations.

CONCLUSIONS

Nose breathing resistance tested with 4PR is lowest in sitting position and highest in supine for most of the study population. Compared supine positions with 30-degree elevation results were variable, but tendency showed that, mostly, resistance is lower during supine position with 30-degree elevation and highest during supine position.

There is an increase in nasal resistance after the transition from sitting to the supine position measured with 4PR in 57% cases. During supine position with 30-degree elevation, nose breathing is worse than during sitting position for 52% of the study population. If we compare measurements during supine position and supine position with 30-degree elevation, ~~then~~ we can see that for half of the study population breathing is better during 30-degree elevation, but worse for 27% and unchanged for 23% – results are variable.

Confirmed dependency of the nasal resistance on posture leads to the conclusion that objective measurement of the nasal resistance by 4PR should be included in the routine diagnostic work in sleep medicine. The information of 4PR is extremely important for the decision about conservative or surgical treatment of the nose before or without a planned prescription of CPAP devices.

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