

Clinical Paper
Orthognathic Surgery

Nasal airway evaluation in obstructive sleep apnoea patients: volumetric tomography and endoscopic findings

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Abstract. Obstructive sleep apnoea (OSA) results from the recurrent collapse of the upper airway during sleep. Nasal abnormalities influence the stability of the pharynx. The aim of this study was to evaluate the volumetric and anatomical changes of the nasal cavity in patients with OSA. The Nasal Obstruction Symptom Evaluation (NOSE) scale was used to grade nasal obstruction. Sleep-related breathing disorders were evaluated by polysomnography. The nasal airway volume was obtained from computed tomography scans through volumetric reconstruction of the nasal airway. Alterations to the nasal anatomy were identified by nasal fiberoptic endoscopy. Ninety-four patient charts were analyzed. The final sample comprised 32 patients with severe OSA, 16 with moderate OSA, 23 with mild OSA, and 20 without OSA. Three groups were established based on nasal obstruction and OSA. The groups were compared for nasal airway volume ($P = 0.464$) and body mass index ($P = 0.001$). The presence of nasal septum deviation and inferior turbinate hypertrophy were related to the NOSE score ($P = 0.05$ for both), apnoea–hypopnoea index ($P = 0.03$ and $P = 0.05$, respectively), and nasal airway volume ($P = 0.71$ and $P = 0.78$, respectively). In this nasal airway evaluation of OSA patients, the presence of sites of obstruction was correlated with the severity of OSA; this was not the case for the evaluation of the nasal airway volume dimensions.

Key words: nasal airway volume; obstructive sleep apnoea; nasal endoscopy.

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Obstructive sleep apnoea (OSA) is a disease that has been increasingly recognized and diagnosed in recent years. Accurate diagnosis and appropriate treatment are key to the management of this illness, which has socioeconomic repercussions

and complications, including an increased incidence of cardiovascular morbidity. The increasing prevalence of overweight in the Western population has been associated with a greater risk of developing OSA and snoring^{1,2}.

The American Academy of Sleep Medicine has defined OSA as a recurrent collapse of the upper airway during sleep, resulting in a total (apnoea) or partial (hypopnoea) reduction in airflow. Primary snoring is a low frequency snore caused by

soft palate and uvula vibrations during sleep³.

A large epidemiological study in the USA involving 5201 adult patients, showed that 19% of women and 33% of men over the age of 65 years snore⁴. Another study demonstrated that approximately 18% of men and 7% of women have snoring problems⁵. An epidemiological study conducted in Sao Paulo, Brazil reported a prevalence of OSA of 32.8% in the adult population⁶.

Risk factors for OSA and snoring include age between 40 and 65 years, male sex, obesity, smoking, alcoholism, and a sedentary lifestyle⁷. The main physical examination findings associated with OSA include increased neck circumference, oropharyngeal obstruction, web palate, nasal obstruction, turbinate hypertrophy, septal deformity, nasal cavity tumours, enlarged tonsils, macroglossia, and retrognathia. Anatomical findings such as vibration factors and a collapsed upper airway have been described in studies that have used cephalometry, computed tomography (CT), magnetic resonance imaging, and nasal fibre-optic endoscopy⁸.

Symptoms may vary among patients, depending on the severity of disease. The most frequent are snoring and excessive daytime sleepiness. Witnessed nocturnal apnoea episodes, choking during sleep, non-restorative sleep, fragmented sleep, enuresis, morning headaches, cog-

nitive decline, memory loss, reduced libido, and irritability are also observed with the development of OSA⁹.

The role of the nose in the pathophysiology of OSA remains uncertain. This is an upper airway disease, in which the main site of obstruction is in the oropharynx. The nose itself may not collapse, but nasal abnormalities influence the stability of the pharynx. Increased nasal resistance limits the airflow, which can decrease intraluminal pressure in the cranial segments of the upper airway¹⁰. Thus the upper airway may resemble a Starling resistor, wherein the upper airway is characterized as a hollow tube, with the nose representing partial obstruction at the inlet and the pharynx representing a collapsible downstream segment¹¹.

Most studies on nose function have been conducted by means of rhinomanometry and acoustic rhinometry evaluations and have shown a diminished nasal volume in OSA patients^{12,13}. A few studies have used CT, but no study has evaluated nasal airway volume by means of CT scans.

The aim of this study was to evaluate the volumetric changes of the nasal cavity in patients with OSA and nasal obstruction.

Methods

This study was conducted in compliance with the rules laid down by the Declara-

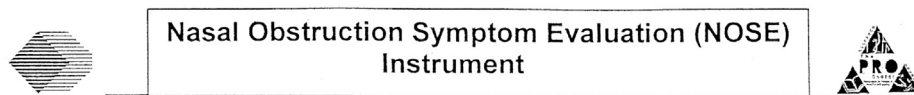
tion of Helsinki and was approved by the Ethics in Research Committee of Araraquara Dental School – UNESP.

This article describes a cross-sectional study conducted by reviewing the medical records of adult patients attending the Oral and Maxillofacial Surgery Clinic, Dental School at Araraquara (UNESP) and the Otorhinolaryngology Clinic, Araraquara University (UNIARA). Patients were evaluated at a specific sleep outpatient clinic.

The following information was obtained from the medical records: dental physical examination, classification of facial morphology, otorhinolaryngology (ENT) examination, upper airway endoscopy, anthropometric variables, body mass index (BMI), baseline polysomnography, and CT scans to define the nasal cavity volume.

Evaluation of nasal obstruction

The Nasal Obstruction Symptom Evaluation (NOSE) scale was used to grade nasal obstruction. The scale consists of five questions, each with a score range of 0 to 4. The scores are added together and multiplied by 5. Thus, the NOSE scale score ranges from 0 to 100. In this study, individuals whose NOSE scale score exceeded 60 points were considered to have nasal obstruction¹⁴ (Fig. 1).



→ To the Patient: Please help us to better understand the impact of nasal obstruction on your quality of life by completing the following survey. Thank You!

Over the past 1 month, how much of a problem were the following conditions for you?

Please circle the most correct response

	<u>Not a problem</u>	<i>very mild problem</i>	<i>moderate problem</i>	<i>fairly bad problem</i>	<i>severe problem</i>
1. Nasal congestion or stuffiness	0	1	2	3	4
2. Nasal blockage or obstruction	0	1	2	3	4
3. Trouble breathing through my nose	0	1	2	3	4
4. Trouble sleeping	0	1	2	3	4
5. Unable to get enough air through my nose during exercise or exertion	0	1	2	3	4

Fig. 1. The Nasal Obstruction Symptom Evaluation (NOSE) instrument used in this study; adapted from Stewart et al.¹⁴.

Evaluation of sleep-related breathing disorders

Polysomnography examinations were performed at the Araraquara Sleep Institute. Sleep was assessed during an average period of 6 h. The parameters evaluated during sleep were electroencephalography (EEG), electrooculography (EOG), electromyography (EMG), electrocardiography (ECG), airflow (nasal and oral), respiratory effort (thoracic and abdominal), other body movements (by means of EMG), blood gases (oxygen saturation, carbon dioxide concentration), and body temperature. The technique used was that defined by the Rules for Scoring Respiratory Events in Sleep of the American Academy of Sleep Medicine (2012 manual).

A medical specialist in sleep calculated each patient's apnoea-hypopnoea index (AHI), which was the sum of the apnoea and hypopnoea events divided by the number of hours of sleep. This index was used to classify the severity of OSA as follows: no OSA (AHI <5 events/h), mild OSA (AHI 5–15 events/h), moderate OSA (AHI 15–30 events/h), and severe OSA (AHI >30 events/h).

Evaluation of nasal airway volume

CT images were obtained with the patient placed in the supine position, with the

head fixed so that the Frankfort plane was perpendicular to the floor. All subjects were instructed to inhale and to hold their breath during image acquisition, exhaling immediately afterwards.

The sections were obtained in the coronal plane, from the anterior nasal spine to the posterior limit of the nasopharynx. All images were stored on a DVD for later analysis using specific software. The three-dimensional images of the CT scans were imported and reconstructed using OsiriX v.7.0 32-bit software (OsiriX Foundation, Geneva, Switzerland) to define the nasal volume¹⁵. Thus, images were generated corresponding to consecutive coronal sections of the region of interest, with spacing of 4 mm.

A trained and blinded observer conducted the evaluation process. The evaluation was repeated for 30% of the sample, by the same evaluator, after a minimum period of 30 days, in order to establish the method error. The values obtained in the re-evaluation were similar to those initially measured.

All measurements were performed on coronal CT slices with a thickness of 0.25 mm and 4 mm distance between slices. To determine the volume of the nasal airway, the area was measured in all CT slices. The outline of the nasal airway was manually traced in each slice by means of the computer trackpad, con-

sidering only the free space of the nasal cavity, i.e. turbinate and septum deviation were not included in the area calculation (Fig. 2). The software tool OsiriX calculated the area automatically. A TIFF image was then generated for each section of the CT for which the area was calculated.

The nasal airway volume for each CT slice was calculated by multiplying the area and height, which was equivalent to the distance between the coronal slices (Fig. 3). The OsiriX software tool calculated the area of the missed slices spaced by 4 mm. The volume of the entire free airway of the nose was the sum of all volumes measured in each slice. The nasal airway volume obtained was similar to a pyramid composed of the free airway space of the nose.

Grading of endoscopic findings

Nasal endoscopy was performed for all subjects included in the study. This was done with a flexible fiberoptic without the use of vasoconstrictor medication. Nasal septum deviation (NSD) was identified when the septum blocked the fiberoptic path and/or there was a contact with the lateral wall of the nose. Inferior turbinate hypertrophy (ITH) was identified when the turbinate blocked the fiberoptic path.

Patients of both sexes, aged between 18 and 70 years, and evaluated between

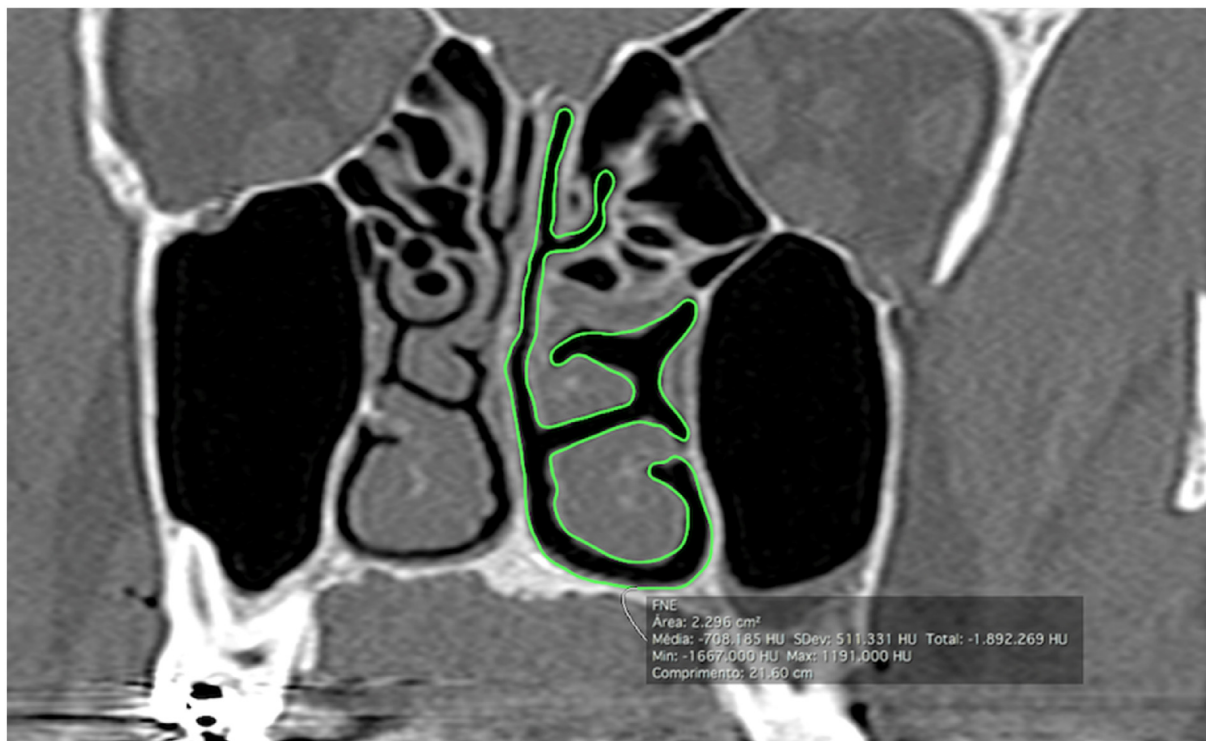


Fig. 2. Nasal airway delimitation on a coronal CT slice.

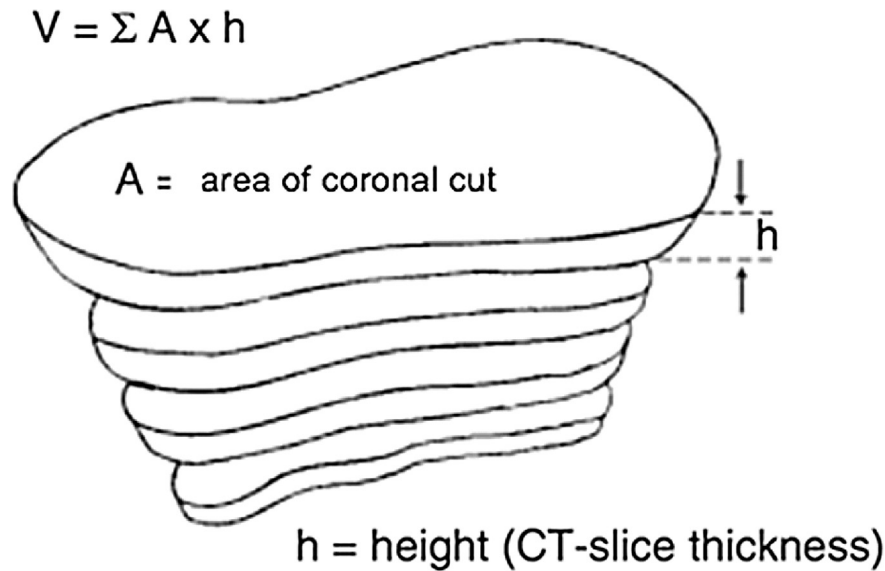


Fig. 3. Nasal airway volume calculation.

December 2014 and December 2015, were included. Patients with the following conditions were excluded: morbid obesity (BMI >40 kg/m²), craniofacial abnormalities (craniodysostosis, craniostenosis, and meningomyelocele), nasal obstruction due to nasal polyps, presence of any craniofacial or airway tumour, laryngeal and pharyngeal paralysis, and previous surgery to the upper airway.

Group allocation

In an attempt to evaluate the effect of OSA and nasal obstruction on nasal airway volume, the individuals in this sample were divided into three groups: (1) group I (control) comprised subjects without OSA (AHI <5 events/h) and without nasal obstruction (NOSE <60 points); (2) group II comprised subjects with OSA (AHI ≥5 events/h) and without nasal obstruction (NOSE <60 points); (3) group III comprised subjects with OSA (AHI ≥5 events/h) and with nasal obstruction (NOSE ≥60 points). These are the three possibilities in the evaluation of the nasal function of subjects with OSA and nasal obstruction symptoms for comparison with a control group.

Results

Ninety-four subjects were evaluated between December 2014 and December 2015. Three patients were excluded from the sample because their CT scans showed poor definition of the limits determined in the methodology, or because the data necessary for the research protocol were

Table 1. Descriptive statistics.

	Min	Max	Mean	SD	Normality test ^a
Age (years)	19.00	76.00	41.07	12.65	0.206
BMI (kg/m ²)	20.80	38.40	29.31	4.05	0.861
NOSE score	10	90	39.92	19.52	0.001
Nasal airway volume (cm ³)	8.79	28.06	17.24	4.25	0.676
AHI	0.4	119.8	29.13	28.32	0.046

AHI, apnoea-hypopnoea index; BMI, body mass index; NOSE, Nasal Obstruction Symptom Evaluation scale; SD, standard deviation.

^a Kolmogorov-Smirnov test.<

incomplete. Therefore, 91 patients were included in the study; 33 (34.5%) were female and 58 (65.5%) were male. The demographic variables are given in Table 1. The distribution of the patients according to the OSA classification is given in Table 2.

The sample was divided into the following groups based on nasal obstruction and OSA: group I (no OSA, no nasal obstruction) comprised 20 subjects, group II (OSA, but no nasal obstruction) comprised 46 subjects, and group III (OSA and nasal obstruction) comprised 25 subjects. The study variables were compared between the groups (Table 3). As the variables showed a normal distribution

Table 2. Description of the OSA classification.

	Frequency	Percentage
Normal	20	22.0
Mild	23	25.3
Moderate	16	17.6
Severe	32	35.2
Total	91	100.0

OSA, obstructive sleep apnoea.

(Table 1), the analysis of variance (ANOVA) test was used.

The groups did not differ significantly with regard to age, nasal airway volume, or sex. However, a statistically significant difference in BMI was observed between the groups (Table 3). In a post-hoc analysis using the Tukey test, a difference in BMI was observed between group I and group II ($P = 0.001$), and between group I and group III ($P = 0.01$). The nasal airway volume data for the three groups are shown in Fig. 4.

The AHI, NOSE scale score, and nasal airway volume were evaluated in relation to the two main nasal endoscopic anatomical variations: NSD and ITH. The results are given in Tables 4 and 5. The NOSE scale score and AHI data did not show a normal distribution, therefore the Mann-Whitney test was used for comparisons. The nasal airway volume data showed a normal distribution and the Student *t*-test was used for comparisons. The nasal airway volume showed no significant relationship with NSD ($P = 0.71$) or ITH ($P = 0.78$). There was a borderline significant relationship between the NOSE scale

Table 3. Comparison of variables between the study groups.^a

	Mean	SD	Percentage	P-value
Age (years)				0.192 ^b
Group I	40.15	16.59	–	
Group II	43.71	12.37	–	
Group III	37.83	11.34	–	
BMI				0.0001 ^b
Group I	25.51	2.50	–	
Group II	29.54	4.25	–	
Group III	29.76	3.26	–	
Nasal airway volume				0.464 ^b
Group I	16.34	3.76	–	
Group II	17.73	4.47	–	
Group III	17.06	4.25	–	
Males				0.142 ^c
Group I			9/20 (45%)	
Group II			32/46 (70%)	
Group III			17/25 (68%)	

ANOVA, analysis of variance; BMI, body mass index; OSA, obstructive sleep apnoea; SD, standard deviation.

^a Group I, patients without OSA and without nasal obstruction; group II, patients with OSA and without nasal obstruction; group III, patients with OSA and with nasal obstruction.

^b ANOVA test.

^c χ^2 test.

score and NSD/ITH data ($P = 0.05$ for both). In the evaluation of the AHI, a marginal relationship with the NSD/ITH data was found ($P = 0.03$ and $P = 0.05$, respectively). These relationships are illustrated in Fig. 5.

Discussion

OSA is a dynamic disease that develops during sleep, involving total or partial upper airway obstruction, on one or more levels. Patients may have one or more sites

of obstruction located in the nasal cavity, oropharynx, at the base of the tongue, and/or in the hypopharynx¹⁶.

Alterations in the upper airway are the main pathophysiology of OSA, and although the collapse occurs in the pharynx, changes at any point in the upper airway can affect the stability of the pharynx. Approximately 50% of OSA patients have symptoms of nasal blockage and/or obstruction¹⁷. The role played by the nose in the pathogenesis of OSA remains unclear. Nasal congestion contributes to the pathogenesis of OSA¹¹. Nasal treatments increase the quality of life and compliance with treatment of some patients with nasal symptoms and OSA. Assuming that the upper airway is a dynamic unit, nasal interventions play a role in the optimization of treatment for snoring and OSA at present¹⁸.

In this study, the nasal airway was evaluated subjectively through an analysis of the NOSE scale. Objective analyses included the nasal airway volume and anatomical alterations seen on endoscopy such NSD and ITH.

Only a few studies have obtained nasal airway volume values using CT scans. Most studies have used acoustic

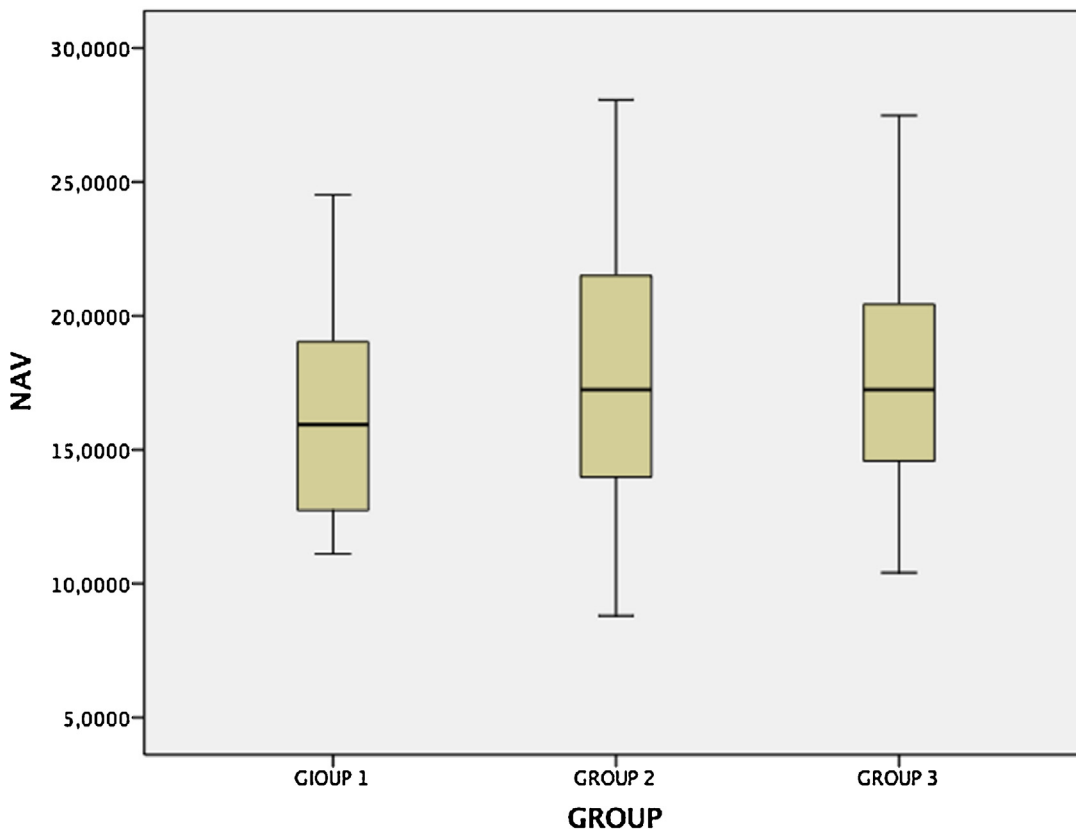


Fig. 4. Box plot of nasal airway volume in the three study groups (group 1, patients without OSA and without nasal obstruction; group 2, patients with OSA and without nasal obstruction; group 3, patients with OSA and with nasal obstruction).

Table 4. Comparison of the study variables according to the presence of septum deviation.

	Septum deviation	Mean	SD	P-value
NOSE score	Yes	43.02	21.73	0.05 ^a
	No	35.45	15.26	
AHI	Yes	31.71	29.18	0.03 ^a
	No	19.46	22.87	
Nasal airway volume	Yes	17.13	4.52	0.71 ^b
	No	17.47	4.08	

AHI, apnoea–hypopnoea index; NOSE, Nasal Obstruction Symptom Evaluation scale; SD, standard deviation.

^aMann–Whitney test.

^bStudent *t*-test.

Table 5. Comparison of the study variables according to the presence of inferior turbinate hypertrophy.

	ITH	Mean	SD	P-value
NOSE score	Yes	45.33	21.69	0.05 ^a
	No	37.28	18.05	
AHI	Yes	33.93	31.42	0.05 ^a
	No	23.10	24.65	
Nasal airway volume	Yes	17.09	5.08	0.78 ^b
	No	17.36	3.98	

AHI, apnoea–hypopnoea index; ITH, inferior turbinate hypertrophy; NOSE, Nasal Obstruction Symptom Evaluation scale; SD, standard deviation.

^aMann–Whitney test.

^bStudent *t*-test.

rhinometry and/or nasal inspiratory peak flow to evaluate the nasal airway volume, for which the data are usually acquired with the patient in an upright position. In this study, CT scans were obtained in the supine position, a favourable position for evaluating patients with OSA, because this disease usually manifests when the patient is lying down in bed. Camacho et al. used cone beam computed tomography in their study and demonstrated that the airway of OSA patients was significantly smaller when the patients

were in a supine position than when they were in an upright position¹⁹.

No significant difference in nasal airway volume was found between the study groups. Nasal airway volume scores were relatively similar across the groups. The nasal airway volume was slightly higher in group II (subjects with OSA and without nasal obstruction) than in the other groups, but not at a statistically significant level. The presence of OSA and nasal obstruction had no influence on the nasal airway volume values. The nasal airway

volume is a variable that evaluates the total free airway space, but it does not evaluate the airflow in the nose. For example, in a patient with a blocked nasal septum deviation, the nasal airway volume will include the volume after the airway blockage, i.e., a site with compromised airflow. In similar studies by de Aguiar Vidigal et al. and Banabilh et al., who used acoustic rhinometry, no significant relationship between OSA and nasal airway volume was found^{20,21}. However, these studies did not consider a group with nasal obstruction in their analyses.

Table 3 shows that there was a significant difference in BMI between the study groups. In the literature, BMI has been shown to have a solid connection with OSA^{4,6}. In the present study sample, patients with OSA (groups II and III) had an increased BMI in comparison to those in the control group (group I), but this relationship was not influenced by nasal obstruction – BMI was similar in group II and group III. Demir et al. observed a statistically significant positive correlation between BMI and an increase in NOSE scale scores; however, the diagnosis of OSA was not considered in their study sample²². Obesity is probably more important than the subject’s nasal symptoms in the evaluation of OSA.

When analysing the nasal endoscopic findings, NSD and ITH showed no relationship with the nasal airway volume; subjects with these findings had similar nasal airway volume values (Tables 4 and 5). Nasal airway volume is a variable that evaluates all free airway space in the nose, whereas NSD and ITH affect the nasal cavity at localized sites. Nasal airway volume includes the free airway behind

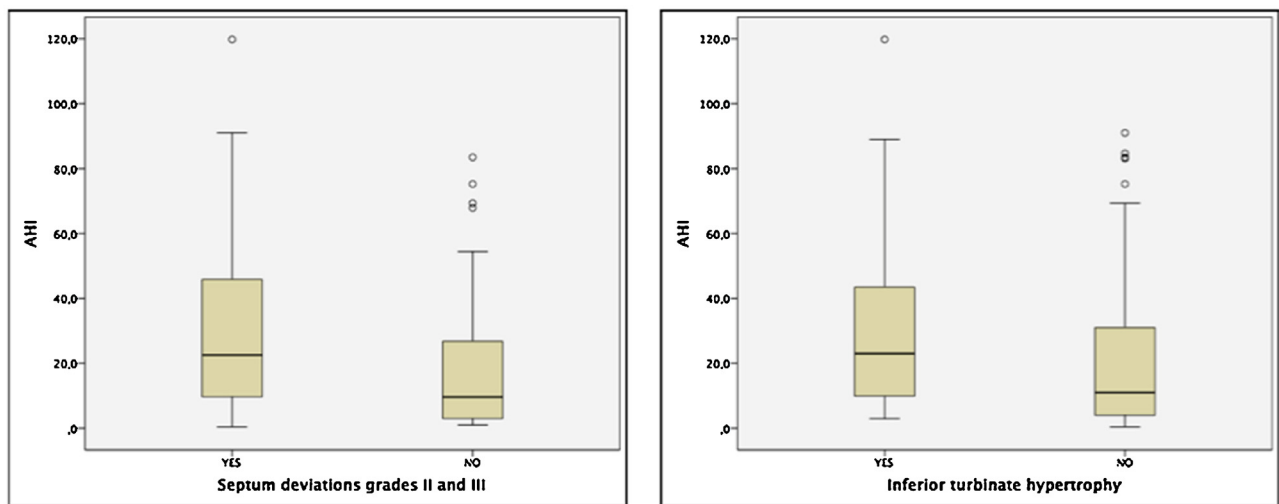


Fig. 5. Relationships between the apnoea–hypopnoea index (AHI) and nasal septum deviation, and between the AHI and inferior turbinate hypertrophy.

an NSD site, or above the ITH, i.e., free spaces in the nose with low airflow due to cranially obstructed sites. For the NOSE scale score and AHI, a significant and positive association was found with NSD/ITH. Sites of obstruction in the nasal cavity had an influence on the nasal symptoms and severity of OSA. de Aguiar Vidigal et al. found similar results in relation to ITH, but not in relation to NSD. Nasal alterations as measured by nasal endoscopy were associated with the presence of OSA²⁰. Abnormal nasal anatomical findings are considered in the evaluation of OSA, and when these alterations are found, they must be treated for a better approach to OSA. Moxness and Nordgård, in an observational cohort study, observed that the effect of nasal surgery on OSA seemed to be greater when combined with surgery to the inferior turbinates and the nasal septum, as compared to septoplasty alone²³.

In this sample, it was demonstrated that endoscopic nasal findings (NSD/ITH) were more important than nasal airway volume when evaluating OSA patients. In the calculation of nasal airway volume, the entire nasal cavity was considered, including the segment after a possible point of maximum obstruction. After this point, there is a gain in airflow that decreases the intraluminal pressure in the caudal segments of the upper airway, leading to a collapse of the upper airway in the pharynx¹⁰.

A site of obstruction in the nasal airway may be more significant than a low nasal volume in the pathophysiology of OSA. Similar results were found by Banabilh et al. using acoustic rhinometry. They demonstrated that the area of minimal cross-section in the nose had a significant relationship with OSA, whereas the relationship between the total nasal volume and OSA was not significant²¹.

In conclusion, in the nasal evaluation of OSA patients, the presence of sites of obstruction, such as nasal septum deviation and inferior turbinate hypertrophy, was found to be significantly correlated with the severity of OSA, and this was not the case for the evaluation of the nasal airway volume dimensions.

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Competing interests

No conflict of interest.

Ethical approval

This study was approved by the Ethics and Research Committee of Araraquara Den-

tal School (registration 13185113.9.0000, report 252.804 dated April 23, 2013).

Patient consent

Not required.

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