Original Article

Three-dimensional upper-airway assessment in patients with bronchial asthma

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ABSTRACT

Objective: To assess the upper airway (UAW) total volume (TV), the nasopharyngeal narrowest area (NNA), and the oropharyngeal narrowest area (ONA) in patients with bronchial asthma.

Materials and Methods: The sample consisted of 52 patients divided into two groups: the control group (n = 26; mean age = 14.85 years), which consisted of patients not suffering from bronchial asthma; and the asthmatic group (n = 26; mean age = 16.65 years), which consisted of patients with bronchial asthma. To assess UAW-related variables (TV, NNA, and ONA), cone-beam computed tomography scans of the patients were evaluated by means of the Dolphin Imaging software 11.5. All measurements were repeated after 30 days, and the results were submitted to reliability tests by means of the intraclass correlation coefficient and the Bland-Altman agreement test. The values obtained for TV, NNA, and ONA for each group were compared by using Student's *t*-test for independent samples (5% level of significance).

Results: The results showed that the groups were matched concerning gender, cephalometric characteristics, and type of malocclusion. The asthmatic group had significantly lower TV ($P = .01$) and ONA ($P = .007$) than the control group. However, no significant difference was observed for NNA between the groups ($P = .54$).

Conclusions: Bronchial asthma may be a determining factor for the reduction of UAW dimensions, as patients with asthma showed significant reductions in TV and ONA dimensions. (*Angle Orthod.* 2014;84:254–259.)

KEY WORDS: Asthma; Tomography; Upper airways

INTRODUCTION

Bronchial asthma is characterized as a chronic inflammation of the lower airways, leading to episodes of partial obstruction of the airflow, which are reversible spontaneously or with drug therapy.[1,2] Such episodes usually occur when a patient inhales an antigen to which he or she is allergic or shows irritation.[3,4]

Although the prevalence of asthma in the adolescent population is nearly 6.9%, the disease has shown a significant increase in incidence in the past few years. Thus, it has become an ever-growing problem in public health, with more than 300 million patients throughout the world.[5]

Even if asthma is described as a pathology of the lower airways, a number of studies have shown that an impairment of the upper airways (UAWs) is often also observed, thereby affecting the normal conditions of craniofacial development.[6–8] Patients with asthma may have a greater prevalence of malocclusions, especially presence of an overbite, an overjet, a maxillary growth deficiency, and a smaller intercanine and intermolar distance, all of which increase the chance of overcrowding, particularly when the disease is established prematurely or before the age of 14.[6,9] Thus, it is important that, when evaluating a child, an adolescent,

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or an adult, the orthodontist observe these signals and symptoms in order to propose a correct treatment for the patient, together with the medical treatment.[6]

Regarding image diagnosis, a lateral cephalogram is part of early orthodontic documentation, and its assessment has allowed orthodontists to observe possible UAW obstructions. Measurements in the sagittal plane, however, are not accurate as this methodology has important limitations, with errors that are inherent to a two-dimensional representation of complex three-dimensional structures.[9–11] Hence, cone-beam computed tomography (CBCT) has been introduced as a new and effective diagnosis method to evaluate UAWs, because images are obtained in three dimensions.[10–14]

Taking into account the lack of studies involving three-dimensional assessment of the UAWs in patients with asthma, this study aimed to test the following null hypothesis: no difference exists between the total volume (TV) of the UAWs, the nasopharyngeal narrowest area (NNA), and the oropharyngeal narrowest area (ONA) in patients with or without bronchial asthma.

MATERIALS AND METHODS

Sample

The protocol of this study was approved by the Research Ethics Committee of the University of North Parana, Protocol Number Pt/0127/11. The sample consisted of 52 CBCT scans, obtained before treatment, from the databases of the University of North Parana. The sample size of each group was calculated based on an alpha significance level of 0.05 and a beta significance level of 0.2 to achieve an 80% testing power. The sample was divided into two groups: the control group ($n = 26$; mean age = 14.85 years), which consisted of patients asymptomatic for bronchial asthma or allergic rhinitis, and the asthmatic group ($n = 26$; mean age = 16.65 years), which consisted of patients with bronchial asthma.

The patients from the asthmatic group were randomly selected from the university database and asthmatic patients who were previously diagnosed (up to six months) by a pneumologist based on health history questionnaires and clinical parameters. Asthma severity was also determined according to the methodology suggested by the Global Initiative on Asthma, which classifies the disease as (1) intermittent, (2) mild and persistent, (3) moderate and persistent, or (4) severe and persistent. These guidelines were prepared to improve medical assistance for patients with asthma because they take into account the degree of the disease. Considering that the disease's severity may be determined based on the severity of the symptoms or on the patient's daily-prescribed medications, both parameters were taken into account.[15] Therefore, the asthmatic group was subdivided regarding severity (intermittent/mild or moderate/severe). These subgroups were equally evaluated as to the proposed null hypothesis.

The patients from the control group were selected from the database of the University of North Parana. They were matched by gender, age, and cephalometric characteristics to the asthmatic group and had no history of respiratory disease. Patients with a history of ear, nose, and throat surgery or with a history of previous orthodontic treatment were excluded from the sample.

Methods

All CBCT scans were carried out by a single experienced radiologist, using the same tomographer (i-Cat Imaging Sciences International, Hatfield, Pa); the scanning protocol was 120kV, 36.9 mA, a 13×23 cm field of view, 0.4-mm voxel, and a scanning time of 40 seconds. While the CBCT was being conducted, the patients were asked not to swallow or move their head during the exam.[13,14] Moreover, the CBCT had to be taken with patients in the intercuspal position to reduce variations of the mandibular position and soft tissue airway measurements often associated with the rest position.[15]

Only one observer evaluated 52 CBCT scans with the Dolphin 3D program (version 11.5, Dolphin Imaging & Management Solutions, Chatsworth, Calif). Before starting the analysis, each patient's head position was corrected with Dolphin software tools using the midsagittal, the Frankfort horizontal, and the transporionic[16,17] planes as references, because small deviations in the position of the head are bound to exist.

UAW TV Assessment

To delimit UAW TV (nasopharynx and oropharynx), the analysis was started by an image sagittal plane reconstruction. Hence, the following anatomic limits were determined sequentially:

1. Lower limit: the caudal medial point of the third cervical vertebra was located and, in a straight line, continued toward the front limit, so that the projection of the posterior nasal spine (PNS) could be seen;[14]
2. Anterior limit: a straight vertical line passing through the PNS point;
3. Upper limit: a horizontal line passing through the lower point in the border of the sphenoidal sinus;
4. Posterior limit: a vertical plane was determined from the upper limit up to the caudal medial point of the third cervical vertebra, so that the anatomic

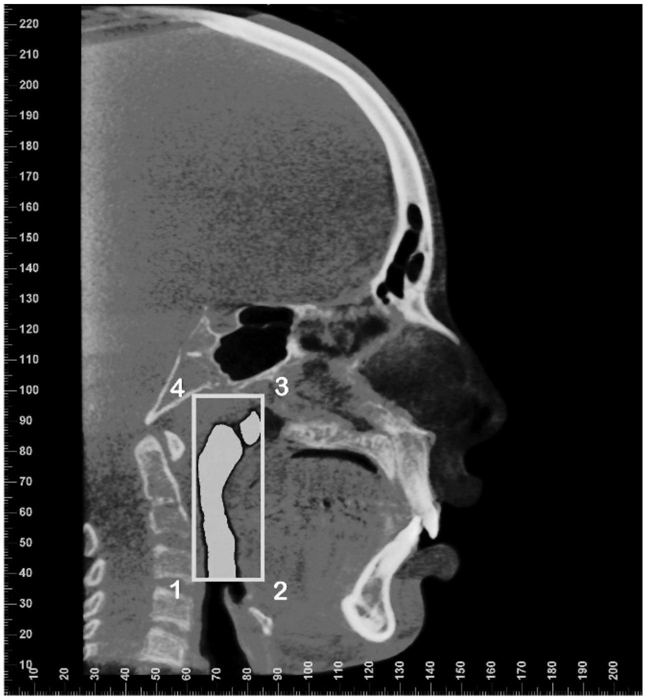

Figure 1. Determination of anatomical limits in the sagittal plane for the total volume (TV) of UAWs: 1. Lower limit: the caudal medial point of the third cervical vertebra was located, and in a straight line, continued towards the front limit, so that the projection of the posterior nasal spine (PNS) could be seen; 2. Anterior limit: a straight vertical line passing through the posterior nasal spine (PNS) point; 3. Upper limit: a horizontal line passing through the lower point in the border of the sphenoidal sinus; 4. Posterior limit: a vertical plane was determined from the upper limit up to the caudal medial point of the third cervical vertebra, so that the anatomic delimitation was completed in the sagittal plane.

delimitation was completed in the sagittal plane (Figure 1).

In addition, the limits were checked in the coronal and axial planes to certify that the lateral wall of the pharynx included all lateral projections. After the anatomic delimitation, the entire aerial space was lined out and filled in with seed points. Another check had to be made in all planes of visualization to make sure that the area lined out with seed points had been totally filled (Figure 2).

UAW NNA and ONA Narrowest Area Assessment

The same anatomic limits determined to calculate TV were used to assess NNA and ONA separately. Thus, for each segmented patch, the program determined the narrowest area, which was quantified in square millimeters (mm^2).

Cephalometric Assessment

Regarding the cephalometric characterization of the groups, lateral cephalograms were obtained based on

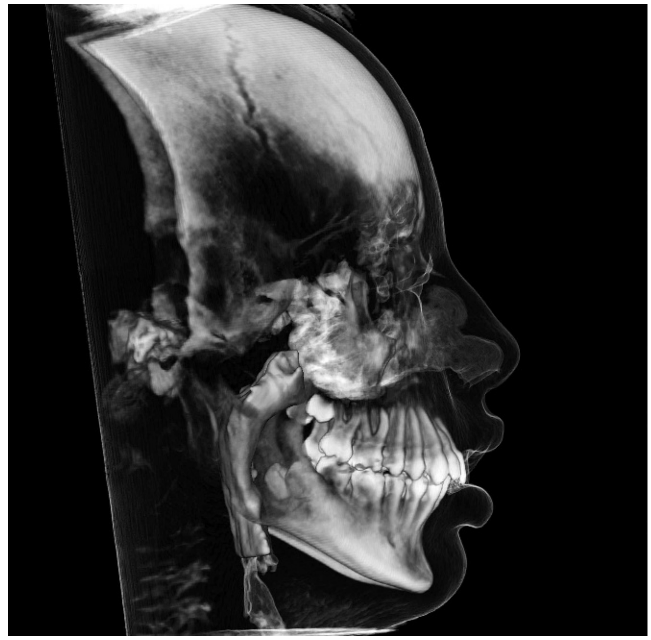

Figure 2. The total volume of UAWs as performed by the Dolphin Software.

the CBCT exams in the Dolphin software in order to evaluate four cephalometric variables: ANB, SNA, SNB, and FMA.

Statistical Analysis

The compatibility of the groups regarding the proportion of malocclusion types (Class I and II) and gender was evaluated by the χ^2 test, and the independent *t*-test was used to evaluate the similarity of the groups in terms of age and cephalometric characteristics. To assess the reliability of the methods used to evaluate the UAWs and cephalometric variables, all measurements were repeated after 30 days, and the results were analyzed using the intraclass correlation coefficient and the Bland-Altman agreement test, according to the criteria described by Fleiss.[18]

The statistical analysis was carried out with the software Statistical Package for Social Sciences version 18.0 (SPSS, Chicago, Il-) and MedCalc version 8.1.0.0 (Mariakerke, Belgium), with a reliability interval of 95% and a significance level of 5% for all tests. The data were shown as mean and standard deviation, after the Shapiro-Wilk normality test.

The independent *t*-test was used to compare the groups concerning the airway variables (TV, NNA, and ONA). Additionally, the asthmatic group was stratified into two subgroups (intermittent/mild or moderate/severe), which were also compared by the independent *t*-test to assess how asthma severity affected the studied variables.

Table 1. Reliability of the Method for Assessing UAW and Cephalometric Variables According to Mean, Standard Deviation (SD), Intraclass Correlation Coefficient (ICC), and Bland-Altman Agreement

	First Measurement		Second Measurement		ICC			Bland-Altman		
	Mean	SD	Mean	SD	ICC	*P*	Error	Bias	Superior Limit	Inferior Limit
Upper airway variables										
TV (mm^3)	16,088.77	5,054.87	16,109.49	5,087.10	0.99	.0001*	0.0003	−20.72	698.50	−739.94
NNA (mm^2)	222.17	84.74	221.35	84.12	0.99	.0001*	0.0006	0.65	15.23	−16.55
ONA (mm^2)	154.12	72.91	157.64	73.20	0.98	.0001*	0.0063	0.98	6.05	−8.02
Cephalometric variables										
SNA (°)	82.38	4.03	82.61	4.15	0.93	.0001*	0.0002	0.23	2.39	−2.86
SNB (°)	78.14	3.91	78.29	4.07	0.95	.0001*	0.0001	0.15	2.33	−2.62
ANB (°)	4.23	2.52	4.40	2.51	0.97	.0001*	0.0177	0.17	1.56	−1.91
FMA (°)	24.69	4.94	24.64	3.02	0.94	.0001*	0.0023	0.04	3.43	−3.34

* Significant at $P < .05$.

RESULTS

The asthmatic and control groups were paired regarding age ($P = .28$), gender ($P = .57$), type of malocclusion ($P = 08$), and cephalometric characteristics (SNA, $P = .10$; SNB, $P = .28$; ANB, $P = .25$; FMA, $P = .19$). Excellent reliability was observed in the methods to evaluate UAWs and cephalometric variables[18] (Table 1).

The asthmatic group had a significantly lower TV (16.76%; $P = .01$) and a lower ONA (25.78%; $P = .007$) than the control group. However, no statistical difference was observed in NNA between the groups ($P = .54$) (Table 2).

No statistical differences were found between TV ($P = .91$), NNA ($P = .31$), and ONA ($P = .07$) between the groups of patients with intermittent/mild or moderate/severe asthma (Table 3).

DISCUSSION

This study compared the dimensions of the UAWs in youths with and without asthma. The TV and the ONA had significantly smaller dimensions for the asthmatic group compared with the control group (Table 2). These results can be explained by the strong relationship of asthma with alterations in the UAW,[3,4,6,19–21] especially chronic allergic rhinitis.[6–8]

Several studies[4,21–24] have shown that asthma and allergic rhinitis are clinical manifestations of the same disease. In fact, rhinitis is a risk factor for the development and aggravation of asthma. Kim and Rubin[22] also suggested a neural interaction between upper and lower airways as the inflammation of the nasal mucosa and the nasal aspiration of secretions in patients with rhinitis induce inflammation of the bronchial mucosa. Moreover, the airway walls were thicker in patients with asthma than in healthy persons, which could indicate a greater narrowing of this region.[6–8]

Gupta et al.[25] evaluated 185 computed tomography scans of patients with severe asthma, and found anatomic abnormalities of the airways in 80% of them. Of these, 62% had greater thickness of the airway walls. In addition, also using quantitative techniques, Aysola et al.[23] and Niimi et al.[24] found the same indexes of thickening of airway walls. These authors found a strong relationship between the thickness of airway walls and the severity and time of occurrence of the asthma as well as an inverse correlation between the thickness of the wall and the airway area.

However, no significant difference was observed for the NNA between the groups in our study (Table 2). These results are probably due to the great topographic variability of the nasopharyngeal region, observed patients with and without asthma. This characteristic of the nasopharynx has been previously described.[4,12–14,26,27]

Table 2. TV, NNA, and ONA in Control and Asthmatic Groups According to Mean, Standard Deviation (SD), and Independent *t*-Test (*P*)

	Control Group		Asthmatic Group		
Variables	Mean	SD	Mean	SD	*P*
TV (mm^3)	16,828.00	4,218.00	14,009.00	3,975.00	.01*
NNA (mm^2)	217.8	79.75	205.4	66.44	.54
ONA (mm^2)	167.90	56.53	124.60	54.19	.007*

* Significant at $P < .05$.

Table 3. TV, NNA, and ONA in the Asthmatic Group by Severity of Asthma According to Mean, Standard Deviation (SD), and Independent *t*-Test (*P*)

	Intermittent/Mild Asthma		Moderate/Severe Asthma		
Variables	Mean	SD	Mean	SD	*P*
TV (mm^3)	13,801.00	4,083.00	13,996.00	4,124.00	.91
NNA (mm^2)	218.50	58.12	190.80	74.84	.31
ONA (mm^2)	102.70	58.53	141.90	45.29	.07

* Significant at $P < .05$.

Asthma has different degrees of severity, which may influence patients' different responses to several conditions.[4,6,21,28] For this sample, however, no statistical difference was found between the groups with intermittent/mild and moderate/severe asthma (Table 3). It may be that when the asthmatic group was stratified for asthma severity, each subgroup had 13 persons, which probably limited the evaluation of this variable. Therefore, studies with a greater number of patients with moderate/severe degrees of severity are suggested to better understand the role of this variable in UAW alterations. In the present study, the asthmatic and control groups were similar in terms of age, gender, type of malocclusion, and cephalometric characteristics.

Taking age into account, the airways show rapid development in childhood; after this period, these structures seem to show little alteration, which only occurs again after adulthood.[26] Regarding gender, Grauer et al.[14] suggested that males have significantly greater volumetric measurements than females, and they emphasized the importance of controlling this parameter when dimensions of the UAWs are assessed. Considering the type of malocclusion (Class I and Class II) when assessing the UAW, Freitas et al.[29] showed that persons with Class II malocclusion with a pattern of vertical development had a narrower pharnyx. Grauer et al.[14] showed that persons with different patterns of maxillomandibular development in the anteroposterior and vertical directions could have differences in the shape of the UAW. Kim et al.[13] showed that the total airway volume in patients with a retrognathic profile was significantly lower than that found for patients with clinically normal growth. In this study, care was taken to match the groups regarding the characteristics described previously, so it was possible to eliminate the interference of these variables in comparisons between the groups.

The sample analysis showed that 52 CBCT scans are sufficient to detect differences between groups, with an 80% testing power. Other studies have evaluated airways with a similar number of patients.[11–14,26,27]

Another relevant aspect was the concern for the standardization of the patients' position and the breathing/swallowing relationship while the CBCT scan was taken. Exams carried out with the patient in a supine position may reflect a mandibular position that is different from that which is habitual.[30] For this study, patients remained seated while the CBCT scans were taken, as this position better reproduces the daily state of the UAWs.[14]

Regarding the results obtained, special attention should be given to patients with bronchial asthma, because the reduction in the dimensions of the airways may reflect the mandibular posture and lip closure, leading to functional and esthetic alterations and malocclusion. Therefore, a multidisciplinary treatment should be proposed in order to reach clinical success and long-term stability.

CONCLUSIONS

- The proposed null hypothesis was rejected because the patients with asthma showed significant reductions in the dimensions of the UAWs.

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