Estimation of nasal cavity volume by coordinates

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Abstract

Aim: The main objective of this preliminary study was to introduce a new approach for the estimation of nasal cavity volume using two dimensional measurements in serial sections, as an alternative to planimetry volume measurements.

Materials and Methods: Ten CBCT images were studied in the coronal plane and the 4-mm thick sections were selected between Anterior and Posterior Nasal Spine. Real estimation of nasal cavity volume was computed using Cavalieri principle in conjunction with planimetry method. The outline of each slice was digitized and the resulted surface area was computed by AutoCAD software. In alternative method, a surface area estimate was measured by multiplying maximum width and maximum height in each slice. The sum of slices area in each method was named as Total Nasal Cavity Area (TNCA). Nasal cavity volume = TNCA × thickness of tomography slice. TNCA1 based on planimetry method, was compared with TNCA2 using to coordinates with linear regression analysis.

Results: Regression analysis showed a powerful correlation between two methods measurements ($r = 0.951$). The following formula was proposed for volume estimation using the coordinate method: TNCA1 = 85.6±1.53 TNCA2.

Conclusions: In this pilot study, we substituted successfully two linear measurements instead of planimetry to estimate nasal cavity volume. This may help investigators to overcome inherent problems appearing in measurements of nasal cavity volume.

Keywords: Cone-Beam Computed Tomography (CBCT), Cavalieri Proinciple, Planimetry, Nasal cavity-Airway

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Nasal respiration contributes to the ideal development of the naso-maxillary complex, therefore; nasal cavity plays a pivot role in etiology of malocclusions.

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The developmental or pathologic changes in this structure may have a significant effect on skeletal growth pattern and on the creation of orthodontic problems due to mouth breathing.[1-3]

Recent orthodontic literature has focused on the relationship between nasal cavity size and nasal airway resistance to evaluate their changes following orthopedic and surgically assisted treatment procedures.

Cone-Beam Computed Tomography (CBCT) has made it possible to acquire accurate images that allow clinicians and researchers to view craniofacial volume in 3 dimensions with minimal distortion and lower radiation dosages. [4-7] Although many studies have been reported in the literature on the various uses of CBCT, studies for assessing the volumetric estimation of craniofacial structures are limited.

Stereological methods, such as Cavalieri, have been used for the volume estimation of many biologic structures. [8-12] By this principle, the total area of parallel sections of any object is calculated and this value is multiplied by the slice thickness. The section areas can be calculated with the planimetric or point counting method. Sectional imaging modalities, such as computed tomography, magnetic resonance imaging, or ultrasonography, may be used for volume estimation using the Cavalieri principle. The estimation of patent pharyngeal airway spaces is possible by sophisticated software, such as Dolphin 3D program and is relatively predictable in pharyngeal areas. In nasal cavity the problem is more complex. The presence of a lot of separate small spaces with variable border density makes the measurements difficult and therefore the reliability would be quite low. Therefore, we decided to use perimetry of nasal cavity instead of measurements of patent spaces. Cavalieri principle could be used to estimate anatomic nasal cavity volume by two-dimensional measurements in serial sections. According to this principle surface area of each slice multiplied by each slice width to provide the total volume. The major drawback of this method is estimation of surface area with perimetry digitization. So we decided to introduce a more simple method of surface area estimation provided by multiplying maximum width by maximum height of nasal cavity in each slice. Accordingly, the primary outcome variable of this study was to compare the estimation of the nasal cavity volume, using coordinates instead of planimetry of each slice, according to CBCT images.

Methods and materials

In this experimental pilot study, 10 available CBCT files taken by Newtom 3G (AFP Imaging, Elmsford, NY) with field of view12, were selected. DICOM (digital imaging and communications in medicine) files were examined by NNT software (Newtom 3G devise related software program) to produce serial coronal sections between Anterior and Posterior Nasal Spine, perpendicular to palatal line (ANS-PNS) with a 4 mm slice thickness.

The volume of the nasal cavity was measured by two different methods. In the 1st method, the surface boundary of each slice was digitized and the surface area was calculated with AutoCAD LT 2007 software (Figure 1).

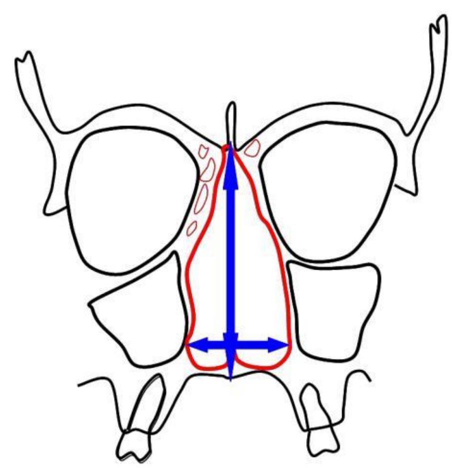

Figure 1:Anatomic nasal cavity surface area in coronal section. Arrows show maximum width and maximum height of nasal cavity

In the 2nd method, the surface area was estimated indirectly using maximum width multiplied by maximum height of nasal cavity in each slice (Figure 2). The sum of slices area in each image was named Total Nasal Cavity Area (TNCA).

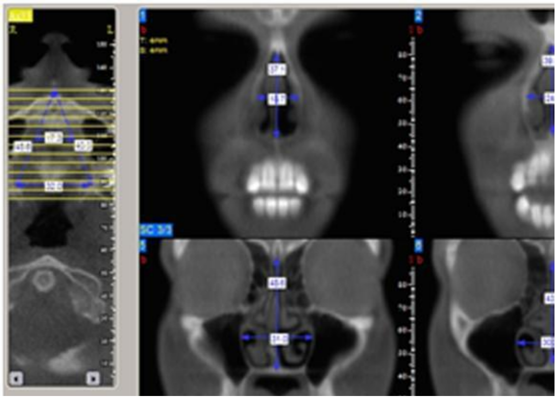

Figure 2: Maximum width and maximum height on serial coronal sections between Anterior and Posterior Nasal Spine

The following formula was used to calculate an estimate of anatomic nasal cavity volume (ENCV): $V = t \times \sum A$ (1)

Where, t is the section thickness and $\sum A$ is the total sectional area of the consecutive sections (TNCA).

All assessments were performed twice by the same examiner. The sum of surface area in each method was compared using Pearson correlation test and regression analysis. The level of statistical significance was set at 0.05.

Results

The sum of surface area (TNCA) in each tomograph in both methods is shown in table 1. In spite of relatively great differences between means, the two methods showed significant correlation coefficient of 0.951 (P value<0.001).

Regression analysis (Fig. 3) showed the proposed method has sufficient power in the estimation of nasal cavity volume (r-square =0.904) According to the following formula,

$TNCA1 = 85.6 \pm 1.53 \times TNCA2$ (2)

Where, TNCA1 and TNCA2 are sums of slices area in each image according to surface area and coordinates, respectively.

According to this pilot study, we could use the proposed nasal cavity indices (height and width) to estimate anatomic nasal cavity volume.

Discussion

Conventional x-ray has limited use in assessing 3D volumes. The drawbacks of this two-dimensional imaging are loss of information, overlay effects, projection errors, and artifacts. Studying the pharyngeal airway by volumetric radiography is preferable because this technology allows visualization in 3 dimensions without magnification or distortion.

The Cone Beam Computed Tomography (CBCT) could be made ideal for the evaluation of pharyngeal airway by low radiation exposure, thin thickness of slices, multiple display modes in combination with high accurate images, minimal superimposition and real size analysis. [4-7]

On the other hand, airway study in nasal cavity has potential complexities. The anatomic structures of the nasal airway can be divided into both positive structures (ie, those formed by tissue) and negative structures (cavities and airways). Changes in soft tissue components (Cartilages, mucosal covering along the turbinates, epithelial tissue and blood vessels) can induce both physiological and pathological changes to airflow. This means that nasal septal deformity, polyps, allergic and non-allergic rhinitis may affect nasal airway patency. Also, the predominant component of nasal air resistance is thought to be the nasal valve, located in a short segment of a few millimeters bridging the piriform aperture 14 so that cross-sectional area of the nasal apparatus does not reflect actually nasal airway resistance, and merely is a surrogate measure for the resistance.

Therefore, although Dolphin 3D program is a valuable tool to compute airway spaces, nasal cavity characteristics including ill-defined 3D borders, multiple separate spaces and variable densities of soft tissue lining make airway volume computation unreliable. Regarding the mentioned limitations, we decided to propose a simple, yet reliable method to estimate anatomic nasal cavity volume. This study introduced a simple approach for estimation of anatomic nasal cavity volume by using two dimensional measurements in serial sections, according to CBCT images. Intra examiner reliability was assessed according to ICC which was 0.991 and 0.996 for AutoCAD and the proposed method, respectively, indicating a high level of repeatability with these CBCT measurement methods. Stereological methods are the objective methods widely used for volumetric analysis in many medical fields. The Cavalieri principle, carried out as a stereological method in this study, was first introduced by Bonaventura Cavalieri. It has been confirmed in many studies as a valid method for volume estimation and it provides unbiased quantitative measurements.[9,12-13] In medicine, several studies have evaluated the accuracy of Cavalieri principle in conjunction with planimetric or point counting method for volume estimation of body structures such as liver, kidney, brain, intervertebral disc, vertebral body, etc. [8-12] Bayram et al. in 2011 evaluated the accuracy of volumetric analysis of the mandibular condyle using cone-beam computed tomography by Cavalieri principle and planimetry method. The planimetric method used by Bayram et al. was the same as AutoCAD method in our study. The results of these studies demonstrated that there was no statistical difference between the volume calculated by the Cavalieri principle and the physical volume. In the present study, we used the Cavalieri principle on CBCT images in the calculation of the anatomic nasal cavity volume.

The value obtained by multiplying the maximum width by maximum height is a good estimate of anatomic nasal cavity volume. The finding of this study may help investigate volume changes in nasal cavity in longitudinal growth studies or after treatment modalities that may alter the morphology of the anatomic nasal cavity, such as rapid maxillary expansion (RME). [15-20]

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