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Evaluation of volume of the sphenoid sinus according to sex, facial type, skeletal class, and presence of a septum: a cone-beam computed tomographic study

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Abstract

We have used cone-beam computed tomographic (CT) images to retrospectively evaluate the influence of sex, skeletal class, facial type, and the presence of septa on the volume of the sphenoid sinus in 172 images from 85 men (mean (SD) age 28 (2) years) and 87 women (mean (SD) age 30 (1) years). Skeletal class and facial type were calculated for each patient from multiplanar reconstructions using NemoCeph® software. Volumetric analysis of the sphenoid sinus was made with the help of the ITK-SNAP® 3.4.0 segmentation software, while the presence or absence of septa in the sphenoid sinus was evaluated with the Carestream 3D Imaging® software 3.4.3. We analysed the results using two-way ANOVA, Student's independent sample *t* test, and Fisher's exact test, as appropriate, and probabilities of <0.05 were accepted as significant. Sex ($p = 0.0946$), facial type ($p = 0.790$), and skeletal class ($p = 0.120$) had no significant influence on the volume of the sphenoid sinus, and nor did the volumes of the right and left sphenoid sinuses ($p = 0.0923$), or the presence of a septum within the sinus ($p = 0.330$) in its volume.

Keywords: Cone-Beam Computed Tomography; Anatomy; Sphenoid Sinus: Anatomical

Introduction

The sphenoid sinuses are paired, air-filled spaces located within the sphenoid bone. They are present as small cavities at birth, and their main development occurs after puberty. In early life they extend posteriorly into the presellar area, and subsequently expand into the area below and behind the sella turcica, reaching full size during adolescence.[1] They are of great importance for functional endoscopic sinus surgery because of their site, which is used for the treatment of intrasellar conditions that encompass the pituitary gland, and for exploration of the anterior cranial base.[2] Endoscopic sinus surgery is also the gold standard in the treatment of chronic rhinosinusitis, which is one of the most common illnesses of our time, and it is increasing in epidemic proportions throughout the world.[3]

The structures that can be reached through trans-sphenoidal surgery depend on the degree and direction of the pneumatisation of the sinuses, which varies from absent to extensive. The sphenoid sinuses have been classified into four types based on the site of the wall of the posterior sinus in respect to the sella turcica: conchal, presellar, sellar, and postsellar.[4] The extension of the sinuses may lead to an increased risk of iatrogenic lesions, as the pneumatisation

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is linked to the probability of damage to important structures, namely the internal carotid artery, the maxillary nerve, and the optic nerve, with internal bleeding, trigeminal neuralgia, and visual deficit, respectively. However, it is not only the degree of pneumatisation that varies, but also the morphology of the sinuses and the possibility that additional septa could segment the air spaces further, which would hinder the navigation of the probe during endoscopic surgery.[5]

Knowledge about the variants of the sphenoid sinuses and the factors that influence them are crucial for surgeons who do endoscopic sinus surgery, as well as for radiologists who are involved in the preoperative investigations. Ethnicity, sex, and age are all factors that have an influence, and it has also been suggested that nasal airflow and positive air pressure in the nasopharynx affect the development of the paranasal sinuses and craniofacial growth.[6] According to some authors the development of the paranasal sinuses is linked directly to the growth of the facial part of the skull and with dentition.[7,8]

The morphology and size of the human paranasal sinuses were initially established from anatomical measurements that were made by injecting different materials into cadavers or taking plain radiographs. More recently, the introduction of computed tomography (CT) with multiplanar reconstructions has allowed a more reliable assessment of these structures.[7] Low dosage requirements, high-quality bony definition, and the compact design afforded by cone- beam CT scanners have made them attractive for preoperative and intraoperative scanning of the paranasal sinuses.[9] Cone-beam CT scans can be used to make linear and angular measurements as well as to evaluate size, shape, and volume by segmentation of structures.

The great variability of the sphenoid sinus, which is considered the most variable cavity in the human body, and its effect, make knowledge of its anatomy essential.[10] The aim in the present study, therefore, was to evaluate the influence of skeletal class, facial type, sex, and presence of a septum on the volume of the sphenoid sinuses by segmentation in cone-beam CT examinations.

Material and methods

The local Ethics Committee approved this work without restrictions under the protocol CAAE 65561317.0.0000.5418.

This retrospective study comprised 172 cone-beam CT examinations from 85 male patients (mean (SD) age 28 (2) years), and 87 female patients (mean (SD) age 30 (1) years), who required the examination for planning of orthodontic or surgical treatment. All examinations were made in a local radiology clinic and were acquired with an i-CAT Next Generation® unit (Imaging Sciences International, Hatfield, PA) with the following variables: 120 kVp, 5 mA, acquisition time 40 s, reconstruction time 62 s, voxel of 0.3 mm, and FOV (field of view) of 23 x 17 cm. The cone-beam CT examinations were obtained with each subject sitting upright and with the Frankfurt horizontal plane parallel to the ground and the patient's teeth occluding in maximum intercuspation.

Patients younger than 21 years of age (whose craniofacial structures are not completely developed) and patients with conditions or syndromes that involved the head and neck were excluded from the study.

Skeletal class and classification of facial type

Skeletal class (class I, II, and III) and facial type (brachycephalic, mesocephalic, and dolichocephalic) were recorded for each patient from multiplanar reconstructions (lateral cephalometric) derived from the cone-beam CT images by an orthodontist, with the NemoCeph® software (Nemotec, Madrid, Spain).

For assessment of skeletal class (class I, II, or III), we used the sella-nasion- angle (SNA), sella-nasion-B angle (SNB) and A point-nasion-B point angle (ANB) measures obtained from Steiner's cephalometric analysis. Patients classified as class II had an increased value of SNA (accentuated development of the maxilla), and class III patients had an increased SNB value (accentuated development of the mandible).

Facial types were differentiated into vertical groups (brachyfacial, mesofacial, dolichofacial) using the VERT index (arithmetic mean of five cephalometric measurements: angle of facial axis, facial depth, angle of mandibular plane, lower facial height and mandibular arch) as calculated in Ricketts' cephalometric analysis. Conforming to the VERT index, a positive value coincided with a brachyfacial type, a negative value to a dolichofacial type, and a value of zero to a mesofacial type.

Measurement of volume

The volume of the sphenoid sinuses was measured with the semiautomatic segmentation mode of the ITK-SNAP® 3.4.0 software (Cognitica). The anterior, posterior, lateral, medial, superior, and inferior walls of the sphenoid sinuses defined the region of interest (ROI) for segmentation. After segmentation, the volumes of the right and left sphenoid sinuses were reconstructed and measured in cubic millimetres (mm^3) by the software (Fig. 1).

Assessment of septum

The presence or absence of a septum in the sphenoid sinus was evaluated using the Carestream 3D Imaging® software 3.4.3 (Carestream Health Inc) by a dynamic evaluation of the cone-beam CT volume in the axial, sagittal, and coronal views. Contrast, brightness, and zoom of the images were adjusted according to each examiner's preference, and they were evaluated in an environment with dimmed lightning.

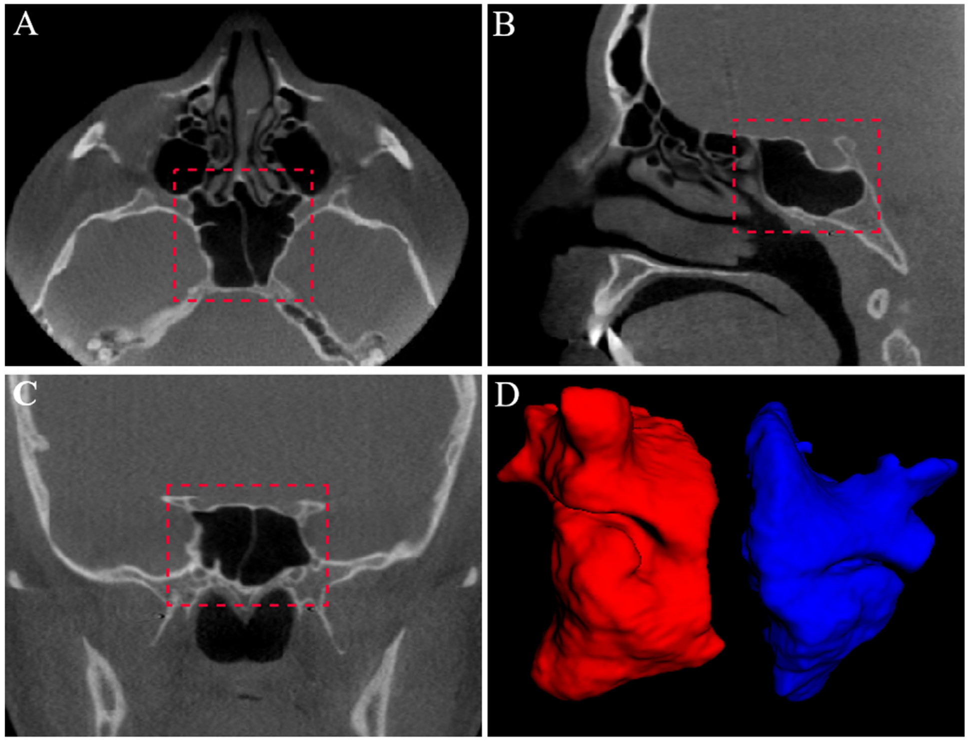

Fig. 1. Delineation of the region of interest in the segments of the sphenoid sinus.
A = axial view, B = sagittal view, C = coronal view, and D = the final image of the volumetric reconstructions of the right and left sphenoid sinuses.

Analysis of images

The volumetric measurements were made by one specialist oral radiologist, and the assessment of the septum was conducted by two specialist oral radiologists, all of whom were experienced in the evaluation of tomographic images and trained in the use of the software.

Statistical analysis

Twenty days after the evaluations, a quarter of the sample was reassessed and the intraclass correlation coefficient (ICC) was used to calculate the intra-examiner agreement. We used the MedCalc Statistical Software version 15.8 (MedCalc Software bvba, 2015) and the two-way ANOVA, the independent sample *t* test, and Fisher's exact test, as appropriate, to assess the significance of differences. Probabilities of less that 0.05 were accepted as significant.

Results

The ICC showed almost perfect intraexaminer agreement for volumetric measurements (0.99), and for the diagnosis of presence of septum (0.81-1).

There was no influence (two-way ANOVA) of skeletal classes ($p = 0.12$), facial types ($p = 0.790$) and sex ($p = 0.0946$) in the sphenoid sinuses volumes. There were also no significant differences between the volumes on the right and left sides ($p = 0.0923$). The presence of the septum had no influence (unpaired t test, $p = 0.335$) on the volume of the sphenoid sinus (Fig. 2).

Discussion

The study of the morphology of the sphenoid sinus became important when surgeons began to require access to the anterior region of the base of the skull for trans-sphenoidal surgery. In-depth knowledge of this region has become essential to predict what may be found, so that possible anatomical variations can be accounted for, and iatrogenic lesions such as damage to the internal carotid artery and other important structures, can be avoided.[11]

To analyse the anterior region of the base of the skull, the method that has become the gold standard in recent years is cone-beam CT,[12,13] and measurements made in this way have replaced earlier methods such as studies in cadavers and plain radiography.[14] Some authors have stated that CT of the paranasal sinuses is essential to make a careful evaluation of all structures in this region,[15,16] and we agree with that, and therefore used it to measure the volume of the sphenoid sinuses.

These volumes were calculated using the semiautomatic segmentation tool available in the ITK-SNAP 3.4.0 software,[15–17] which was validated by its developers for clinical research in neuroimaging,[17] and has been proved to be extremely reliable.[18]

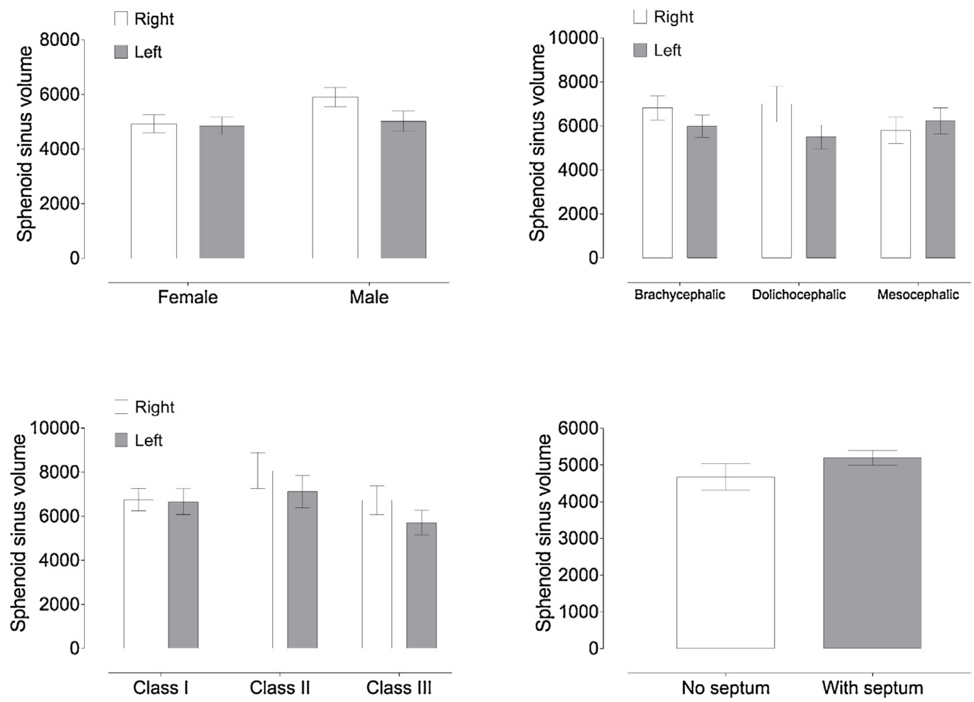

Fig. 2. Graphs that compare the volume of the sphenoid sinus (mm^3) according to sex, facial type, skeletal class, and presence of septa.

The measurements of volume in the sphenoidal sinus gave us important information. For example, some studies have stated that the sphenoid sinus can be used as a criterion for sexual dimorphism, but this is still controversial. Some authors have found significantly larger volumes in men than women,[19,20] but our results were similar to those of other studies[21–23] that reported no significant differences in volumes between the sexes. These divergent findings may be explained by the different ethnicities and sizes of samples assessed.

We found no significant differences between volumes depending on side, whereas some found differences between right and left,[22] and another reported results that were similar to ours.[20] The contrasting results may reflect differences in sample size, as we evaluated 172 images, while Oliveira et al in 2017[22] assessed 47, and in 2009, 50.[19]

Because the sphenoid sinus is so important in the surgical management of the pituitary gland, and because it may provide access to other parts of the base of the skull, the evaluation of its volume in patients with different craniofacial morphology is of considerable relevance.[4] As far as we know, this is the first study in which the volume of the sphenoid sinuses has been evaluated in patients of different skeletal classes and facial types. The sphenoid sinus in patients with skeletal class II contained greater volumes than those with classes I and III, but they did not differ significantly, and nor were there any significant differences between facial types.

The septa of the sphenoid sinus are commonly found in the paranasal sinuses, being highly variable.[14] They are made up of thin cortical bony walls, the numbers of which vary in thickness and length. The presence of septa can result in morphological variations of the sinus, so recognition of the presence of septa may be helpful in the accurate identification of the internal carotid artery, and so reduce the risk of injury to it.[10,24] We found larger volumes in sphenoid sinuses with septa, but again the differences were not significant. We therefore recommend that special attention is paid to class II patients, as they had larger volumes in the sphenoid sinus in the presence of septa.

We think that the results of the present study can be used to provide a better anatomical understanding of the sphenoid region, which is necessary for endoscopic surgeons and radiologists who need to be familiar with the skull base, and we also recommend that further studies should be done to increase the knowledge of this region to avoid possible complications in diagnostic evaluations and operative procedures. We conclude therefore that skeletal class, facial type, sex, and the presence of septa exert no influence on the volumes of the sphenoid sinuses.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

The local Ethics Committee approved this work without restrictions under the protocol CAAE 65561317.0.0000.5418. Patients' permission was obtained.

References

1. Mohebbi A, Rajaeih S, Safdarian M, et al. The sphenoid sinus, foramen rotundum and vidian canal: a radiological study of anatomical relationships. *Braz J Otorhinolaryngol* 2017;**83**:381–7.
2. Gibelli D, Cellina M, Gibelli S, et al. Volumetric assessment of sphenoid sinuses through segmentation on CT scan. *Surg Radiol Anat* 2018;**40**:193–8.
3. Alsowey AM, Abdulmonaem G, Elsammak A, et al. Diagnostic performance of multidetector computed tomography (MDCT) in diagnosis of sinus variations. *Polish J Radiol* 2017;**82**:713–25.
4. Štoković N, Trkulja V, Dumić-Čule I, et al. Sphenoid sinus types, dimensions and relationship with surrounding structures. *Ann Anat* 2016;**203**:69–76.
5. Gibelli D, Cellina M, Gibelli S, et al. Anatomical variants of sphenoid sinuses pneumatisation: a CT scan study on a Northern Italian population. *Radiol Med* 2017;**122**:575–80.
6. Selcuk OT, Erol B, Renda L, et al. Do altitude and climate affect paranasal sinus volume? *J Craniomaxillofac Surg* 2015;**43**:1059–64.
7. Sánchez Fernández JM, Anta Escuredo JA, Sánchez Del Rey A, et al. Morphometric study of the paranasal sinuses in normal and pathological conditions. *Acta Otolaryngol* 2000;**120**:273–8.
8. Wolf G, Anderhuber W, Kuhn F. Development of the paranasal sinuses in children: implications for paranasal sinus surgery. *Ann Otol Rhinol Laryngol* 1993;**102**:705–11.
9. Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 2: clinical applications. *AJNR Am J Neuroradiol* 2009;**30**:1285–92.
10. Dal Secchi MM, Dolci RLL, Teixeira R, et al. An analysis of anatomic variations of the sphenoid sinus and its relationship to the internal carotid artery. *Int Arch Otorhinolaryngol* 2018;**22**:161–6.
11. Pohlenz P, Blessmann M, Blake F, et al. Clinical indications and perspectives for intraoperative cone-beam computed tomography in oral and maxillofacial surgery. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007;**103**:412–7.
12. Liang X, Jacobs R, Hassan B, et al. A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT) part I. On subjective image quality. *Eur J Radiol* 2010;**75**:265–9.
13. Güldner C, Pistorius SM, Diogo I, et al. Analysis of pneumatization and neurovascular structures of the sphenoid sinus using cone-beam tomography (CBT). *Acta Radiol* 2012;**53**:214–9.
14. Kapur E, Kapidžić A, Kulenović A, et al. Septation of the sphenoid sinus and its clinical significance. *Int J Collab Res Intern Med Public Health* 2012;**4**:1793–802.
15. Farias Gomes A, de Oliveira Gamba T, Yamasaki MC, et al. Development and validation of a formula based on maxillary sinus measurements as a tool for sex estimation: a cone beam computed tomography study. *Int J Legal Med* 2018 https://doi.org/10.1007/s00414-018-1869-6.
16. Grauer D, Cevidanes LS, Styner MA, et al. Pharyngeal airway volume and shape from cone-beam computed tomography: relationship to facial morphology. *Am J Orthod Dentofac Orthop* 2009;**136**:805–14.
17. Yushkevich P, Piven J, Hazlett HC, et al. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. *Neuroimage* 2006;**31**:1116–28.
18. Weissheimer A, de Menezes LM, Sameshima GT, et al. Imaging software accuracy for 3-dimensional analysis of the upper airway. *Am J Orthod Dentofac Orthop* 2012;**142**:801–13.
19. Oliveira JX, Perrella A, Santos KC, et al. Accuracy assessment of human sphnoidal sinus volume and area measure and its relationship with sexual dimorphism using the 3D-CT. *J. Health Sci Inst* 2009;**27**:390–3.
20. Cohen O, Warman M, Fried M, et al. Volumetric analysis of the maxillary, sphenoid and frontal sinuses: a comparative computerized tomography based study. *Auris Nasus Larynx* 2018;**45**:96–102.
21. Emirzeoglu M, Sahin B, Bilgic S, et al. Volumetric evaluation of the paranasal sinuses in normal subjects using computer tomography images: a stereological study. *Auris Nasus Larynx* 2007;**34**:191–205.
22. Oliveira JM, Alonso MB, de Sousa e Tucunduva MJ, et al. Volumetric study of sphenoid sinuses: anatomical analysis in helical computed tomography. *Surg Radiol Anat* 2017;**39**:367–74.
23. Yonetsu K, Watanabe M, Nakamura T. Age-related expansion and reduction in aeration of the sphenoid sinus: volume assessment by helical CT scanning. *AJNR Am J Neuroradiol* 2000;**21**:179–82.
24. deMiranda CM, Maranhão CP, Arraes FM, et al. Anatomical variations of paranasal sinuses at multislice computed tomography: what to look for. *Radiologica Brasileira* 2011;**44**:256–62.