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Evaluation of basilar expansion and internal septa of human sphenoidal sinus using cone beam computed tomography

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ABSTRACT | The objective of this study was to assess the types and frequencies of basilar expansion of the sphenoidal sinus and internal septa by using cone beam computed tomography. Archived images from 300 adult subjects of both genders were retrieved. A descriptive analysis relating age and gender to basilar expansion of the sphenoidal sinus and internal septa types and frequencies was performed. The associations between basilar expansion of the sphenoidal sinus, internal septa and gender for each age group were assessed using the chi-square test or Fisher's exact test. Among all the images evaluated, 69% showed basilar expansion of the sphenoidal sinus, of which 81% were considered critical. Internal septa were observed in 60% of the images. There was no relationship between the presence of basilar expansion of the sphenoidal sinus and gender and age. Internal septa were independent of gender; however, of the subjects older than age 40, 36% had only a main septum, 6% had accessory septa, and 18% had both types of septa. Cone beam computed tomography is an accurate method that should be considered for the evaluation of this anatomic segment in order to avoid unnecessary exposure to radiation.

DESCRIPTORS | Paranasal Sinuses; Sphenoid Sinus; Anatomy; Cone Beam Computed Tomography.

RESUMO | **Avaliação de expansão basilar e septos internos do seio esfenoidal humano por meio de tomografia computadorizada de feixe cônico** • O objetivo deste estudo foi avaliar os tipos e as frequências de expansão basilar do seio esfenoidal e septos internos utilizando tomografia computadorizada de feixe cônico. Imagens arquivadas de 300 indivíduos adultos de ambos os gêneros foram recuperadas. Foi realizada uma análise descritiva relacionando idade e gênero à expansão basilar do seio esfenoidal e a tipos de septos internos e frequências. As associações entre expansão basilar do seio esfenoidal, septos internos e gênero para cada grupo de idade foram avaliadas por meio do teste do qui-quadrado ou teste exato de Fisher. Entre todas as imagens avaliadas, 69% apresentaram expansão basilar do seio esfenoidal, das quais 81% foram consideradas críticas. Septos internos foram observados em 60% das imagens. Não houve relação entre presença de expansão basilar do seio esfenoidal, gênero e idade. Septos internos apresentaram-se independentes do gênero; no entanto, dentre os indivíduos com mais de 40 anos de idade, 36% tinham apenas um septo principal, 6% tinham septos acessórios, e 18% tinham ambos os tipos de septos. A tomografia computadorizada é um método preciso que deve ser considerado para a avaliação desse segmento anatômico a fim de evitar a exposição desnecessária à radiação.

DESCRITORES | Seios Paranasais; Seio Esfenoidal; Anatomia; Tomografia Computadorizada de Feixe Cônico.

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INTRODUCTION

The sphenoidal sinus (SS) and its variation between individuals and between sides of the same skull were described by Zuckerkandl in 1893.[1] This variability underlies the reason for the few papers published in the literature defining the standard sinonasal configuration and the significance of its internal septa (IS) and limits. Considering the range of imaging resources currently available, it seems important to explore this anatomic structure with the object of contributing to the study of human anatomy.

The basilar expansion of the sphenoidal sinus (BESS) is a posterior expansion located anteriorly and inferiorly to the clivus. It was studied to better understand its relevance in performing endoscopic or microscopic endonasal surgical interventions, including access to the SS itself, and in using transsphenoidal pituitary approaches. Inappropriate surgical planning, or even an inaccurate approach during surgery, may cause significant damage, such as clival perforation or internal carotid artery injury.[2-5]

The use of cone beam computed tomography (CBCT) has been growing. This technique combines high-quality images, owing to its isotropic voxels, with low-radiation doses, as compared to helical computed tomography (HCT).[6-7] Revision of tissue-weighting factors in the 2007 International Commission on Radiological Protection (ICRP) recommendations considered the cancer incidence data that was not available when the 1990 guidelines were drawn up. Weighted tissues and organs and revised weights in the 2007 recommendations are justified because of accumulated epidemiologic information on the tumorigenic effects of radiation that is now sufficient for estimating cancer risks. Because of cumulative X-ray risks, defining strategies for dose reduction is imperative, including the choice of radiographic unit. However, to date, patients are mostly submitted to HCT examinations and to their high-radiation doses for SS evaluation or surgical planning.[7-9]

The aim of this study was thus to investigate the presence and type of BESS and IS in human SS by using CBCT, and correlate the data with gender and age. Validating this imaging method for SS evaluation is also one of the study objectives.

METHODS

Archived images from 300 adult subjects of both genders were retrieved from the files of a private radiology clinic located in the city of Campinas, SP, Brazil. The images had been obtained using a CBCT device (i-Cat 3D Dental Imaging System; Imaging Sciences International, Hatfield, PA, USA), set at the following parameters:

- scan time, 40 s;
- field of view, 13 cm;
- 120 kVp;
- 36 mA; and
- pixel size, 0.25 mm.

All images selected for this analysis were of high quality, therefore allowing accurate SS evaluation and interpretation. Only patients with no history of neurological or paranasal sinus surgery were considered for this study. Any type of intervention in this area could cause IS changes or other anatomical damage, potentially invalidating the results of this study.

The analysis was conducted using Xoran software (Imaging Sciences International, Hatfield, PA, USA) provided by the CBCT device, which allows evaluation of axial and sagittal views, and identification of the BESS and the IS. The image selected for evaluation was that which presented the foramen lacerum in the most posterior part of the SS in the axial view. This central image was the image of choice for SS evaluation.

Following the Haetinger[1] protocol, the presence or absence of BESS was evaluated considering

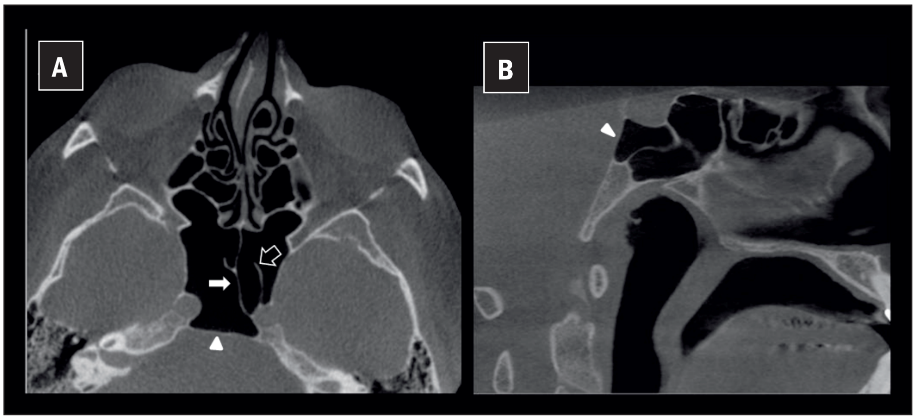

Figure 1 | **A:** Axial view; **B:** sagittal view. Presence of a critical basilar expansion of the sphenoidal sinus (white arrow head), main septum (white arrow), and accessory septum (black arrow).

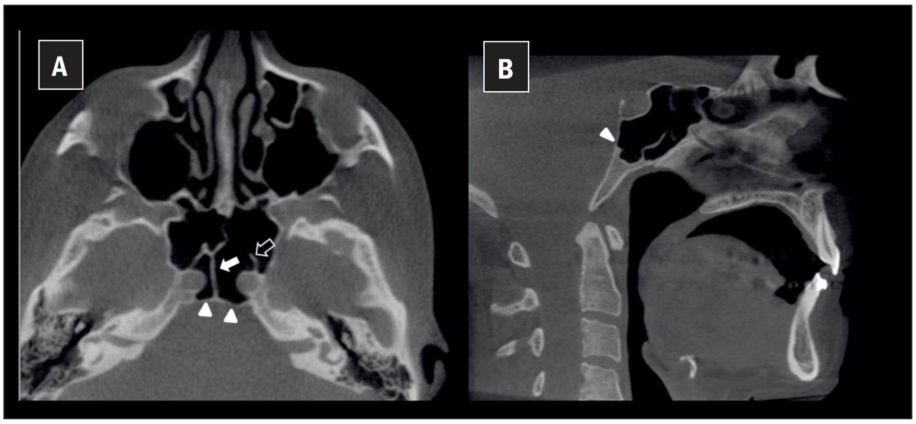

Figure 2 | **A:** Axial view; **B:** sagittal view. Presence of bilateral critical basilar expansion of the sphenoidal sinus (white arrow head), main septum (white arrow), and accessory septum (black arrow).

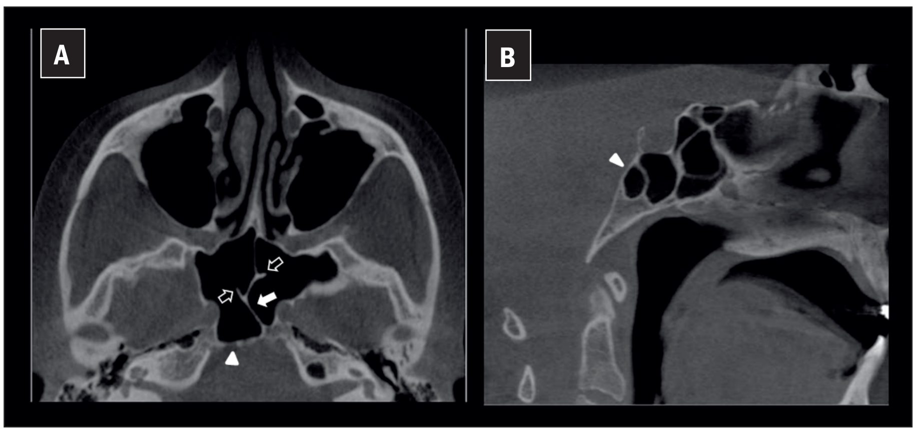

Figure 3 | **A:** Axial view; **B:** sagittal view. Presence of a unilateral, critical basilar expansion of the sphenoidal sinus (white arrow head), main septum (white arrow), and accessory septa (black arrow).

the anterior portion of the foramen lacerum as its limit. When expansions were found, they were classified as unilateral or bilateral and, based on posterior SS wall thickness, as critical or noncritical. The wall thickness was measured using a software tool; when the wall thickness was less than 2 mm, the SS was classified as critical. The presence of IS and its types, i.e., main septum or accessory septa, was also evaluated (Figures 1 through 3)

A descriptive analysis relating gender and age to

BESS and IS types and frequencies was performed. The associations between BESS, IS, gender, and age were evaluated using the chi-square test and Fisher's exact test. The chi-square test evaluates the association between categorical variables in a contingency table with R rows and C columns. When the expected frequency is less than 5, it is appropriate to use Fisher's exact test instead.

For all the tests, a p-value corresponding to 5% was considered significant. All the analyses were performed using SAS software for Windows, v.9.3.1 (SAS Institute, Cary, NC, USA).

The percentages of subjects with IS (main, accessory, and both) were obtained among the total subjects. These percentages were compared using the proportion difference test. This test is based on the chi-square test and determines whether the proportions are equal (homogeneity proportion test). This test was performed on the total sample and was also stratified according to gender.

This study was conducted ethically and was approved by the Research Ethics Committee, School of Dentistry, University of São Paulo (Brazil).

RESULTS

Among all the 300 images evaluated, 69% showed BESS, of which 81% were considered critical. IS was observed in 60% of the images.

Table 1 presents the association of the presence or absence of BESS with gender and age. These results, as assessed using Fisher's exact test, show no association between BESS and gender at various ages.

Table 2 presents the relationship between critical and noncritical expansions, age, and gender. These results show no association between unilateral and bilateral BESS, critical and noncritical BESS, and gender at various ages.

Table 3 shows the relationship between septa and gender at various ages. According to Table 3, there is no correlation between IS and gender.

Table 1 | Association between BESS and gender at various ages.

Age	Gender	Without basilar expansion	With basilar expansion	Total
20–29	Male	5	12	17
	Female	3	8	11
	Total	8	20	28
		P = 1.0000*		
30–39	Male	8	16	24
	Female	12	24	36
	Total	20	40	60
		P = 1.0000*		
40–49	Male	9	25	34
	Female	5	26	31
	Total	14	51	65
		P = 0.3749*		
50–59	Male	10	29	29
	Female	12	19	31
	Total	22	48	60
		P = 0.3033*		
60–69	Male	14	15	29
	Female	9	15	24
	Total	23	30	53
		P = 0.5787		
70–79	Male	4	10	14
	Female	2	8	10
	Total	6	18	24
		P = 1.0000*		

*Fisher's exact test.

However, there is a relevant correlation between septa and gender for the following age groups:

- 30–39,
- 40–49,
- 60–69, and
- 70–79.

Table 4 presents the logistic regression model, with BESS as a response variable, and gender and age as explanatory variables. According to this table, age and gender have no effect on the occurrence of BESS; in other words, the occurrence of BESS is independent of age and gender, as deter-

Table 2 | Association between critical and noncritical basilar expansion, gender, and age.

Age	Gender	Basilar expansion					
		Critical			Noncritical		
		Unilateral	Bilateral	Total	Unilateral	Bilateral	Total
20–29	Male	0	10	2	0	2	2
	Female	0	7	7	0	1	1
	Total	0	17	17	0	3	3
		P = **			P = **		
30–39	Male	0	14	14	0	2	2
	Female	2	15	17	2	5	7
	Total	2	29	31	2	7	9
		P = 0.4882*			P = 1.0000*		
40–49	Male	2	18	20	0	5	5
	Female	2	20	22	0	4	4
	Total	4	38	42	0	9	9
		P = 1.0000*			P = **		
50–59	Male	4	21	25	0	4	4
	Female	2	11	13	0	6	6
	Total	6	32	38	0	10	10
		P = 1.0000*			P = **		
60–69	Male	0	11	11	0	4	4
	Female	0	13	13	0	2	2
	Total	0	34	34	0	6	6
		P = **			P = **		
70–79	Male	2	6	8	0	2	2
	Female	0	8	8	0	0	0
	Total	2	14	16	0	2	2
		P = 0.4667*			P = **		

*Fisher's exact test; **No test was performed because of an excessive frequency of zero.

mined using the chi-square test (Table 1). A greater standard error than that expected would give an odds-ratio confidence-interval value of 1, indicating that the presence or absence of basilar expansion is independent of gender and age.

DISCUSSION

The SS is highly variable in regard to size and format, and expansions are often observed. Its thin walls can render its relationship with neighboring structures critical, thus requiring a more careful surgical approach.[1] In this study, basilar expansion was observed in 69% of the cases.

The presence of septa and projections is more frequent in the SS than in other paranasal sinuses[10] due to the fusion lines between bone components of the SS and its development process.[11] SS development starts at 3 or 4 months of fetal life as a cartilaginous capsule. Ossification starts in the fifth month of fetal life, but fusion to the sphenoid bone occurs only by the fourth year after birth. Areas of bone resistance to pneumatization may occur at the junction points, resulting in IS formation.[12]

The presence of BESS promotes contact be-

Table 3 | Association between septa and gender at various ages.

		Septa			
Age	Gender	Main	Accessory	Both	Total
20–29	Male	1	0	4	5
	Female	2	2	0	4
	Total	3	2	4	9
		P = 0.0476*			
30–39	Male	8	2	3	13
	Female	15	2	7	24
	Total	23	4	10	37
		P = 0.7743*			
40–49	Male	14	0	9	23
	Female	11	4	4	19
	Total	25	4	13	42
		P = 0.0485*			
50–59	Male	20	4	7	31
	Female	11	6	4	21
	Total	31	10	11	52
		P = 0.4205*			
60–69	Male	6	0	9	15
	Female	11	0	0	11
	Total	17	0	9	26
		P = 0.0024**			
70–79	Male	2	0	7	9
	Female	7	0	0	7
	Total	9	0	7	16
		P = 0.0032**			

*Fisher's exact test; **Fisher's exact test excluding the zeros.

tween the foramen lacerum and IS.[1] BESS may also be close to other important adjacent structures, or even promote the attachment of IS from ossification center junctions to these adjacent structures.[2] These aspects explain the importance of studying SS and identifying BESS and IS, in order to avoid errors during surgical interventions.[3]

The surgical importance of these anatomical variations (BESS and IS),[13,14] in conjunction with the precise anatomical knowledge of the SS and its variations, is crucial when a surgical approach is necessary.[1] These are all confirmed by HCT, an imaging method that contributes to better understanding craniofacial complexity.[15] A great variety of SS formats and sizes is frequently investigated,[16] and HCT provides accurate linear and volumetric data for anatomic evaluation of the SS, as well as for that of neighboring structures.[1, 17-20]

In 1998, a different technique of computed tomography based on a cone beam was presented.[21] This technique (CBCT) is also highly accurate for maxillofacial diagnosis, including linear, angular, and volumetric measurements, and provides improved image quality for dental structures and nearby structures.[6,22,23] On the other hand, multislice HCT has proved only slightly more accurate than CBCT for making linear and volumetric measurements.

In fact, the most important advantage of CBCT is its low-radiation dose as compared to that required by HCT.[7-9,24] Loubele *et al.*[9] compared the effective dose levels of CBCT with HCT for maxillofacial applications, according to 2007 ICRP guidelines. Effective dose values ranged from 13 to 82 µSv for CBCT and from 474 to 1160 µSv for HCT. The authors concluded that CBCT dose levels are lower than those used in HCT protocols. This reduced dose, combined with ease of use and economic accessibility, highlights the importance of using CBCT technique for BESS and IS evaluation.

Our results show that the BESS can be visualized with CBCT, since the BESS frequency found in this study (Tables 1 and 2) is in agreement with that reported in the related literature.[5,25-28] This means that changing the imaging method from HCT to CBCT did not affect or jeopardize the proposed SS analysis. The same occurs with the IS evaluation, insofar as the IS frequency was 60% in our study (Table 3), whereas the related literature reports an endoscopically determined IS frequency of 68.8%.[4]

The related literature also describes the presence or absence of BESS as independent of patient

Table 4 | Logistic regression model with and without BESS variables.

Without basilar expansion					
Variable	Estimated	Standard error	P value	OR	CI 95%
Gender					
Male	−0.0482	0.1278	0.7060	0.908	0.550–1.499
Female	1	-	-	-	-
Age					
20–29	−0.0820	0.3697	0.8244	1197	0.348–4.119
30–39	0.1612	0.2663	0.5450	1527	0.522–4.465
40–49	−0.4506	0.2835	0.1119	0.828	0.276–2.482
50–59	0.0590	0.2527	0.8155	1379	0.481–3.952
60–69	0.5747	0.2662	0.0309	2309	0.790–6.747
70–79	1	-	-	-	-

OR, odds ratio; CI 95%, confidence interval of 95%.

gender or age,[29,30] an observation confirmed by the results obtained in our study (Tables 1, 2 and 4). Additionally, in accordance with the study by Haetinger *et al.*,[1] 81% of all BESS cases were classified as critical, highlighting the importance of this evaluation for surgical planning.[1-3,13-15,26] In contrast, there was a strong correlation between IS frequency and patient age, starting at age 30, regardless of gender (Table 3).

In conclusion, CBCT proved a valuable tool for the evaluation of both BESS and IS. It provides high-quality images using low-radiation doses, and should therefore be considered for the evaluation of this anatomic segment. Neither BESS nor IS was found to be gender-dependent, and their high frequencies indicate that they should be taken into consideration when planning a surgical intervention.

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