

ORIGINAL STUDY

CT study of the sphenoid sinus pneumatization types

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ABSTRACT

BACKGROUND. Development of the skull base surgery imposed thorough knowledge of sphenoid anatomy, its pneumatization types, especially hyperpneumatization, which causes difficulty in endoscopic approach by modifying the classical anatomical relations to vital vascular-nervous structures in the neighbourhood.

MATERIAL AND METHODS. We conducted a retrospective anatomo-imagistic study for a period of 11 months, on 50 CT scans having as target organ the region of facial sinuses, in general population, with various symptoms. The cranio-facial CT scans were made with a spiral, multiplan, high resolution technique.

RESULTS. The research determined the prevalence value for each type of sphenoidal pneumatization (according to Lang's classification), for the types of sphenoidal hyperpneumatization. Selar and hypersinus types have been identified as the most frequent; we investigated the correlations of the sphenoid pneumatization types with patients age, sex and location of pneumatization (unilateral, bilateral).

CONCLUSIONS. Sphenoid pneumatization may present different aspects, from the hyperpneumatized sinuses to a small sphenoid sinus, giving variety and uniqueness to this sinus. Sphenoid hyperpneumatization may be an anatomic variant or an epiphenomenon of tumor pathology and causes significant changes in classical relations of the sinus with the vascular structures, the nerves, increasing the surgical risk.

KEYWORDS: sphenoid sinus, sphenoid pneumatization, CT scan

INTRODUCTION

In the last decades, development of the skull base surgery, approaching a borderline pathology, sometimes in a simultaneous intervention with a complex team, neurosurgical and rhinologic endoscopist, imposed increasing knowledge of anatomy of the posterior ethmoid and the sphenoid.

The sphenoid sinuses, a pair structure in the body of the sphenoid bone, with drainage through the sphenothmoidal recess into the nasopharynx, is located in the infero-medial region compared to the posterior ethmoid. This aspect is particularly important in sphenoidotomies: after the posterior ethmoidectomy, the dissection area is infero-medial, outside this area being a risk of penetration into the anterior cranial fossa or the orbit¹. Usually, the sphenoid sinus develops asymmetrically, having an unequal pneumatization, while the intersinus septum is most of the times deviated, having variable shapes; one of the sinuses may present a major in-

trasinus septum and some minor ones in 56% of the cases, according to Ouaknine G. E².

Intrasinus septa can have posterior insertion on the internal carotid artery canal, especially in the bulging variant, increasing the risk of damage the vessel with dramatic consequences. The optic nerve and the internal carotid artery may present bulging and dehiscence in the sinus^{3,4}. In 75% of the cases, in the well-pneumatized sinuses, there is optic nerve impression on the lateral sinus wall⁴, which can be visualized endoscopically and represents an orientation landmark to be avoided. The sphenoid sinus ostium opens in the lower part of the anterior wall, medial and posterior as compared to the superior turbinate tail, which is an important landmark for its identification; usually, the ostium has a hidden position, provided by the location of the middle concha.

The upper wall of the sphenoid is in relation to the hypophysis. The sella turcica is bordered anteriorly by the tuberculum sellae, a small prominence on the sphenoid bone⁵, and posteriorly by the dorsum sellae,

an elevation of the sphenoid bone, which marks the upper extension of the clivus.

The lateral wall is in relation with the cavernous sinus through which pass: the internal carotid artery and on its lateral side the abducens nerve, the oculomotor nerve, the trochlear nerve and the ophthalmic branch of the trigeminal nerve.

The marks produced by the optic nerve and the internal carotid artery are of considerable clinical importance and depend on the degree of pneumatization of the sphenoidal sinus. If the clinoid process of the lesser wing of the sphenoid bone is pneumatized, there might be a deep recess, the infraoptic recess, situated in the upper part of the lateral wall of the sphenoid sinus^{6,7}, clearly separating the optic nerve from the internal carotid artery. If the anterior clinoid process is not pneumatized, the optic nerve is sometimes difficult to identify endoscopically, because it is not prominent on the lateral intrasinus wall. The superior bulge of the optic nerve extends horizontally near the roof of the sinus, from posterior to anterior in the supero-lateral part of the sphenoid sinus and usually disappears towards the anterior wall. The bony optic canal may have varying degrees of intrasinus dehiscence.

Hudgins P.A.⁸ states that the optic nerve might have a posterior intraethmoid or intrasphenoid trajectory in about 25% of the cases, being subjected to barotraumas or neuritis, as in the hyperpneumatization of the anterior clinoid process.

The sphenoid sinus has a primary pneumatization from the fourth intrauterine month, by posterior evagination of the primitive nasal capsule; at about 2-3 years, it undergoes a secondary pneumatization that accelerates up to 7 years, slowly continuing in adults too. This process varies from one individual to another, even for the same persons, usually asymmetrically, with great variability in the form of the sinus. The extreme forms, hy-

perpneumatization and minimal pneumatization, raise particular problems of intraoperative orientation, by modifying the relationships with the vascular structures and the nerves, requiring experience, thorough knowledge of anatomy and a very good manuality.

The classification of sphenoidal pneumatization types varies from one author to another. Hamberger CA, Hammer G, Norlen G and collaborators⁹ consider there are 3 pneumatization types: conchal, preselar and selar. Lang¹⁰ adds a fourth type, the postselar one, where extension of the pneumatization is on the posterior side of the sella turcica. The variant with absent sphenoid sinus is very rare. Assessment of the pneumatization will take age into account, since the sinus reaches its almost definitive dimensions at 20 years.

THE STUDY PURPOSE

1. Showing the prevalence of the:
 - sphenoidal pneumatization types, according to Lang's classification: conchal, preselar, selar, postselar
 - sphenoidal hyperpneumatization
2. Reveal that different associations of these different sphenoidal pneumatization types with age, sex, location

MATERIAL AND METHODS

The anatomo-radiological study is retrospective for the period January 2010 - November 2010, including 50 patients with different related symptoms in outpatient or emergency room from Buzău who performed a CT scan examination. The including criteria allowed an evaluation in the general population. Subjects were

Table 1
Case distribution according to the patients' age

age [years]	Number of cases	%
10 < age ≤ 20	1	2
20 < age ≤ 30	7	14
30 < age ≤ 40	5	10
40 < age ≤ 50	5	10
50 < age ≤ 60	11	22
60 < age ≤ 70	8	16
70 < age ≤ 80	12	24
80 < age ≤ 90	1	2
Total	50	

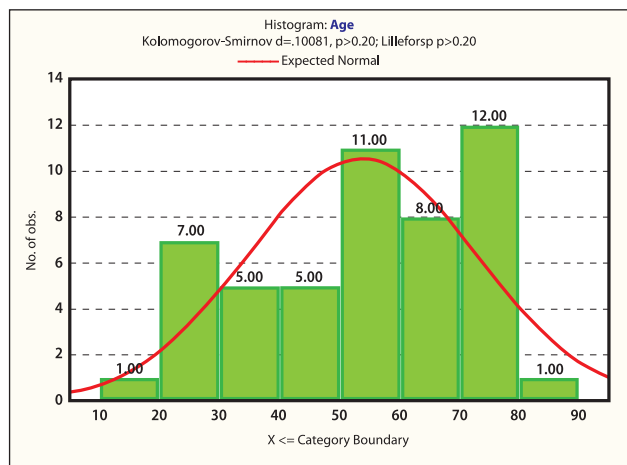


Figure 1 Histogram of patients' age in the study lot

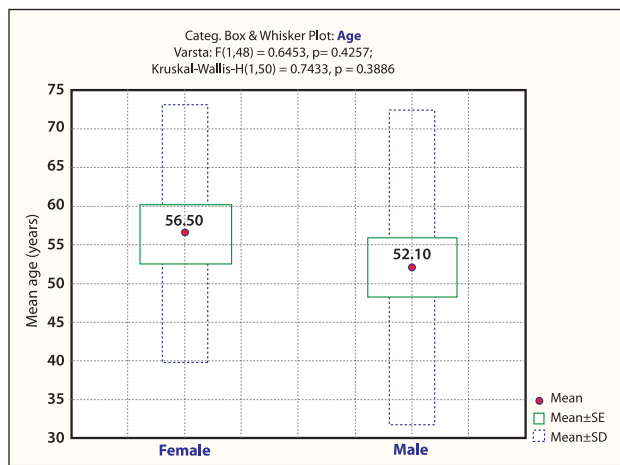


Figure 2 The average age of the cases according to the patients' sex

aged 10-86 years old, 30 male (60%) and 20 female (40%). Spiral tomography technique was used to expose the facial sinuses for better image accuracy, allowing complex bone reconstruction.

Distribution of cases according to age (Table 1, Figure 1) shows a higher frequency of subjects between 50-80 years (62% of the lot). The series of age values represents an uneven distribution, aspect due to the high frequency of the age group of 20-30 years old and lower frequency of the 30-50 years old, respectively 60-70 years old age groups. The analysis took into account the normalization of data, in order to eliminate any errors caused by the uneven distribution. Age-related statistical indicators of the selected lot are shown in Table 2 and in Figure 2.

Patients' average age was 53.86 ± 18.9 years, 52.10 ± 20.3 years for men vs. 56.5 ± 16.7 years for women (Figure 2), subjects between 50-80 years old prevailing. Case distribution according to sex is shown in Table 4, while Table 3 presents the comparison of the patients' average age according to sex.

We used 2 mm axial CT sections (from the archive of the Medical Imaging and Radiology Department of the Buzău County Emergency Hospital), in double window (bone and tissue), with coronal and sagittal bone reconstructions. Coronal images are usually used for preopera-

tive rhino-sinusal endoscopic assessment, providing the same view as during surgery, with the uncinate process and ethmoid bulla represented vertically and the most relevant information about the ostiomeatal complex. Nevertheless, in the case of the posterior ethmoidal cells, sphenoid sinus and their relationships with the optic nerve/internal carotid arteries, the best orientation with the most details is provided by the axial plane.

The device used (Figure 3) was a Philips AURA CT scanner, with MRC-162 X-Ray Tube, 160 mm anode, 10° target angle, rotation speed of 8100 rpm, movement speeds of 5mm/sec and 100mm/sec, 100 MB CD-R (1300 images), minimum reconstruction index of 0.1 mm, milliamperage between 60-100 mAs, commonly used for CT.

Figure 4 shows the position of axial images initially obtained per patient, and how they were chosen for bone slices reconstruction sites.

Sagittal reconstruction revealed the pneumatization type of the sphenoid sinus, determining the location of the pituitary gland. The relationship of the sphenoidal sinus with the posterior ethmoid and the pneumatization of the clinoid processes and of the dorsum sellae have been researched on the axial and sagittal incidences. Coronal incidences also revealed the relation of the sphenoid and the ethmoid to the

Table 2 Age-related statistical indicators according to the patients' sex

	Age mean	Mean		Std. Dev.	Std. Err.	Min.	Max.	Q25	Median	Q75
		-95%	+95%							
Female	56.50	48.68	64.32	16.70	3.73	20	82	46	61	64
Male	52.10	44.51	59.69	20.32	3.71	22	80	34	53	72
All Groups	53.86	48.49	59.23	18.90	2.67	20	82	37	56	72

Table 3
The test comparing mean values vs. patients' sex

Age	F (95% confidence interval)	p
ANOVA Test	0.645345	0.425742

Table 4
Cases distribution according to patients' sex

	No. of cases	%
Female	20	40%
Male	30	60%
Total	50	

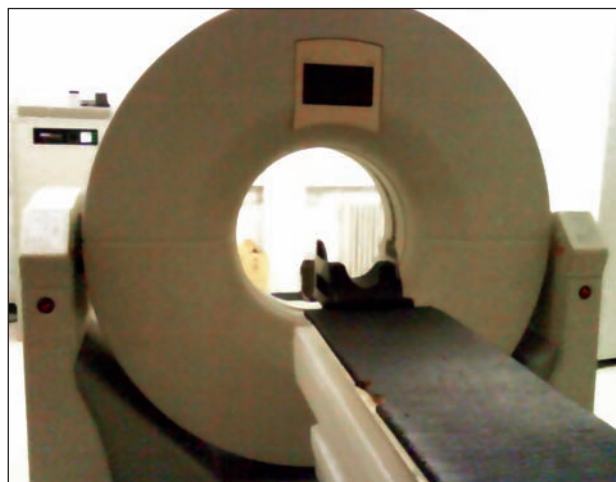


Figure 3 CT scanner used by the Buzău County Emergency Hospital

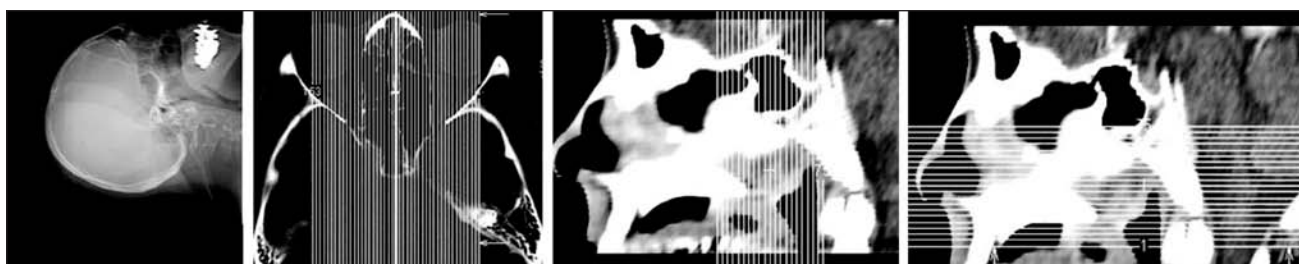


Figure 4 The patient's position during the CT scan examination, with image reconstruction scheme for sagittal and coronal slices

optic nerve or the relationship between the sphenoid and the internal carotid artery.

We investigated the pneumatization degree of the sphenoid sinus (normal, hyperpneumatized, small or hypoplastic sinus) with identification of the four types: conchal, preselar, selar, postselar, adhering to Lang's anatomico-clinical classification¹⁰. We better assessed the extent of the antero-posterior and lateral pneumatization on the axial sections, the antero-posterior, inferior and superior extent on the sagittal reconstructions, and the lateral, superior and inferior extent on the coronal sections. The conchal sinuses were considered small or hypoplastic. The prevalence of each type and of sphenoidal hyperpneumatization was correlated with patients' age and sex.

We qualitatively evaluated the sphenoidal sinus hyperpneumatization, adhering to Dupuche's considerations¹¹: the rectilinear or curvilinear appearance of the edges, their thickness or mineralization, excessive pneumatization in the neighbouring structures. According to the classification of different authors, including Bell AF, Ivan DF, Munson RA,¹² Reicher MA, Bentson JR, Halbach VV, Lufkin R and Hepler RS,¹³ sinus hyperpneumatization can give rise to 3 categories:

1. megasinus (hypersinus);
2. pneumosinus dilatans: extension beyond the boundaries, convex walls, without thinning;

Table 5
Cases distribution according to the type of sphenoid sinus pneumatization

Pneumatization Type	No. of cases	%
Conchal	7	14%
Preselar	22	44%
Selar	41	82%
Postselar	1	2%
Total	50	

3. pneumocele (pneumatocoele): normally pneumatized sinus or extended beyond the boundaries, with partial or total thin walls.

RESULTS

1. Sphenoidal pneumatization types

Sphenoidal pneumatization types (Tables 5-6, Figures 5-7) have shown the selar form as the most frequent, in 41/50 cases (prevalence of 82%), followed by the preselar type in 22/50 cases (prevalence of

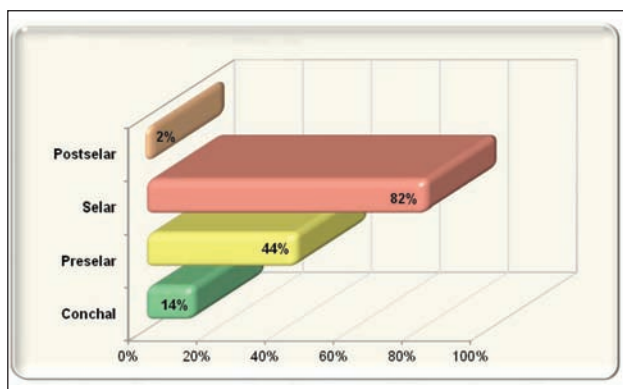


Figure 5 Cases distribution according to the type of sphenoid sinus pneumatization

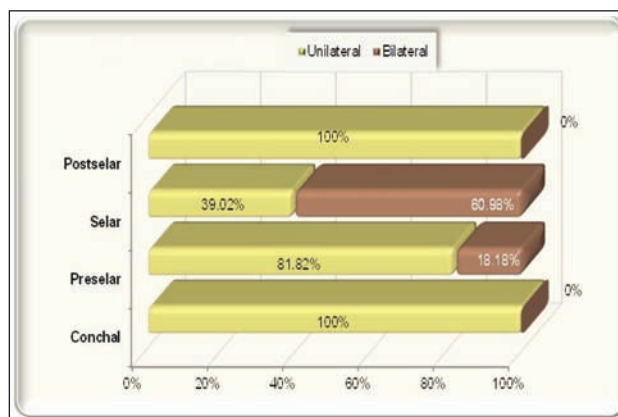


Figure 6 Prevalence of the sphenoid sinus pneumatization types

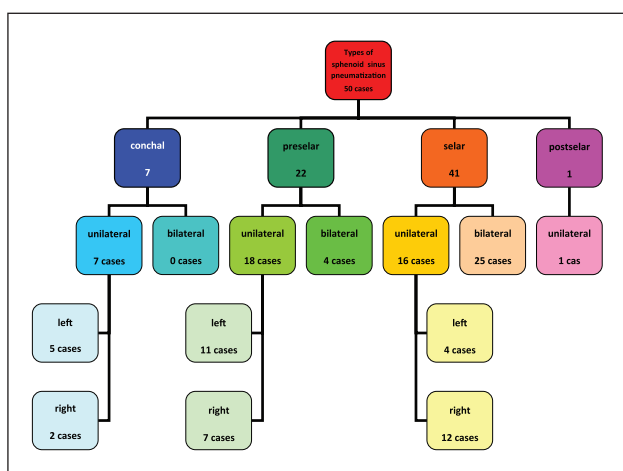


Figure 6 Cases distribution according to the type and the location (unilateral/bilateral) of the sphenoid sinus pneumatization

44%), the conchal type in 7/50 cases (prevalence of 14%), the last being the postselar type (1 case, prevalence of 2%).

Cases distribution according to the sphenoidal pneumatization types is shown in each group in Figure 7.

There is a significant association between the sphenoidal pneumatization type and its bilateral or unilateral location (Table 6). Thus, there is a significant association between the selar type and the bilateral one (60.98%), postselar and conchal pneumatization is only unilateral, while in the case of the preselar type there were only 18.18% bilateral pneumatizations ($\chi^2=24.4$, $p<<0.05$, 95% CI), as it is shown in the estimation of the statistical parameters in Table 7.

The four mentioned types of pneumatization of the sphenoid sinus were evaluated for the left and right sides, including both unilateral and bilateral forms (Table 8, Figure 8).

The statistical research shows that the selar type is the most frequent, both on the right side (where there is a higher percentage of cases, 74%) and on the left side, with a total percentage of 58%. The second in frequency pneumatization type is the preselar one, with a value on the studied lot of 30% on the left and 22% on the right. The lowest percentages were recorded for the postselar sinus, a single case, on the left side, with a prevalence of 2%. The conchal sinus, with 7 cases, has a prevalence of 10% on the left side and 4% on the right.

Table 6 Case distribution according to the type of sphenoid sinus pneumatization

Types of sphenoid pneumatization	Unilateral		Bilateral		Total
	No. of cases	%	No. of cases	%	
Conchal	7	100%	0	0%	7
Preselar	18	81.82%	4	18.18%	22
Selar	16	39.02%	25	60.98%	41
Postselar	1	100%	0	0%	1
Total			50		

Table 7
Estimated parameters – pneumatization type vs. location (unilateral/bilateral)

(df=1)	Chi-square χ^2	p 95% confidence interval
Pearson Chi-square χ^2	24.44453	0.00000
M-L Chi-square	27.51539	0.00000
Correlation coefficient (Spearman Rank R)	0.7457627	0.00002

Table 8
Pneumatization type of the sphenoid sinus

Pneumatization type	Left sphenoid sinus		Right sphenoid sinus	
	No. of cases	%	No. of cases	%
Conchal	5	10%	2	4%
Preselar	15	30%	11	22%
Selar	29	58%	37	74%
Postselar	1	2%	0	0%
Total	50			

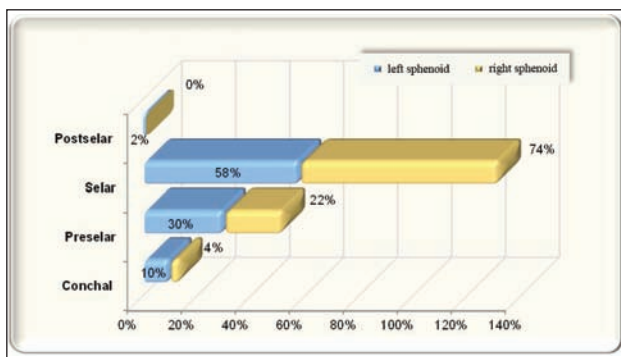


Figure 8 Pneumatization type of the sphenoid sinus

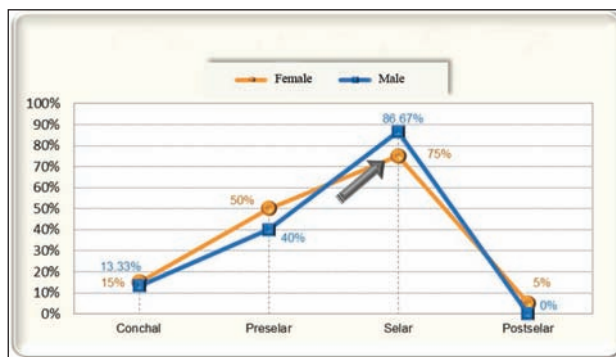


Figure 9 Pneumatization type of the sphenoid sinus vs patients' sex

Correlation of the pneumatization type with patients' sex and age

Table 9 and Figure 9 show the distribution of the different pneumatization types in male and female subjects, where the selar type is dominant, with 86.67% and, respectively, 75%. Estimated parameters in association of pneumatization type vs. patients' sex (Table 10) reveal the fact that there is a significant association between the type of sphenoidal pneumatization and patients' sex ($\chi^2=2.54$, $p=0.467$, 95% CI).

Statistical indicators of patients' age depending on the pneumatization type are presented in Tables 11-12 and in Figure 10.

Statistical analysis (Table 12 and Figure 10) showed the absence of significant differences between patients' average ages depending on the type of sphenoidal pneumatization ($F=0.24$, $p=0.862$, 95% CI).

These different degrees of pneumatization led to various forms of the sphenoidal sinuses, with different combinations, which can be observed in the selected images in Figures 11-13.

2. Sphenoidal hyperpneumatization

Unilateral sphenoidal hyperpneumatization (Table 13, Figure 14), with 13 cases and a prevalence of 26%, was more frequent than the bilateral one, with 5 subjects and a prevalence of 10%. Left unilateral forms were more frequent.

Table 9
Pneumatization type of the sphenoid sinus vs. patients' sex

Pneumatization type	Female		Male	
	No. of cases	%	No. of cases	%
Conchal	3	15%	4	13.33%
Preselar	10	50%	12	40%
Selar	15	75%	26	86.67%
Postselar	1	5%	0	0%
Total	20		30	

Table 10
Estimated parameters - type of sphenoid sinus pneumatization vs. patients' sex

(df=1)	Chi-square χ^2	p 95% confidence interval
Pearson Chi-square - χ^2	2.543417	0.46750
M-L Chi-square	2.888834	0.40909
Correlation coefficient (Spearman Rank R)	0.1263158	0.60771

Table 11
Age-related statistical indicators according to the sphenoid sinus pneumatization type

	Age mean	Mean		Std. Dev	Std. Err.	Min	Max	Q25	Median	Q75
		-95%	+95%							
Conchal	52.57	35.36	69.78	18.61	7.03	22.00	79.00	37.00	53.00	64.00
Preselar	56.24	45.77	66.70	20.36	4.94	20.00	80.00	44.00	60.00	74.00
Selar	52.20	44.42	59.98	18.85	3.77	22.00	82.00	36.00	54.00	72.00
Postselar	64.00	-	-	-	-	64.00	64.00	64.00	64.00	64.00

Table 12
The test comparing the average age vs. sphenoid sinus pneumatization type

Age	F (95% confidence interval)	p
ANOVA test	0.248468	0.862007

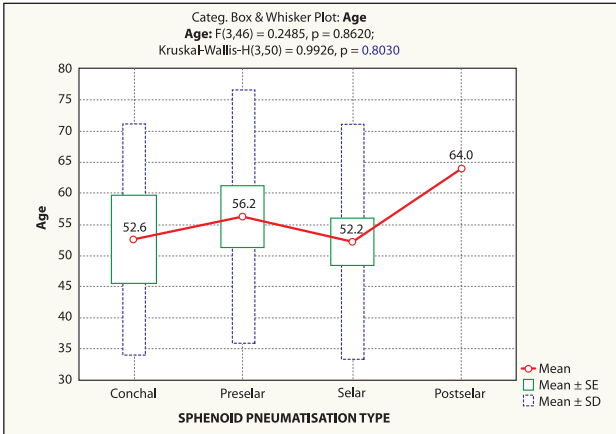


Figure 10 The average age of the cases vs. sphenoid sinus pneumatization types

As with the other sinuses, the degree of pneumatization for this lot included the whole range of expression, from hypoplasia to pneumatocoele.

Figures 15-18 reveal aspects of the sphenoidal hyperpneumatization found in the evaluated subjects.

DISCUSSIONS

1. Types of pneumatization of the sphenoid sinus

Classification of types of sphenoid pneumatization varies from one author to another. Sareen D., Agarwal K. A., Kaul M. J. and Sethi¹⁴ consider there are two types of pneumatization of the sphenoid sinus: preselar and postselar.

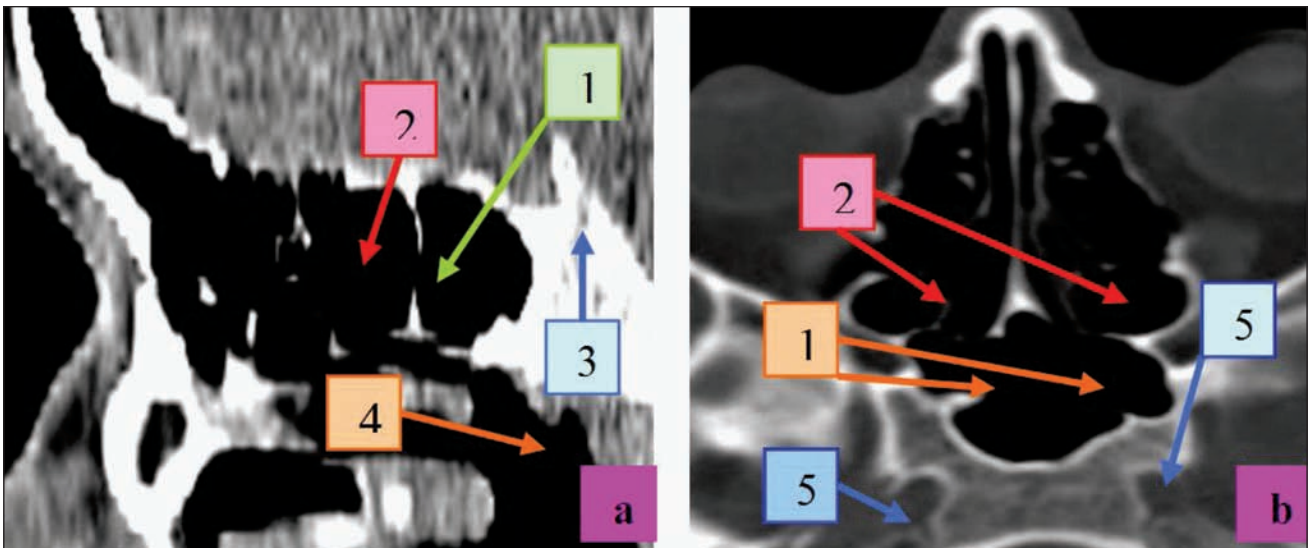


Figure 11 Cranio-facial CT scan coronal. Preselar pneumatization of the sphenoid sinus: a) sagittal reconstruction; b) axial slice: 1. Sphenoid sinus - preselar type; 2. hyperpneumatization of the posterior ethmoidal cells; 3. clivus; 4. rhinopharynx; 5. internal carotid arteries away from the sphenoid sinus

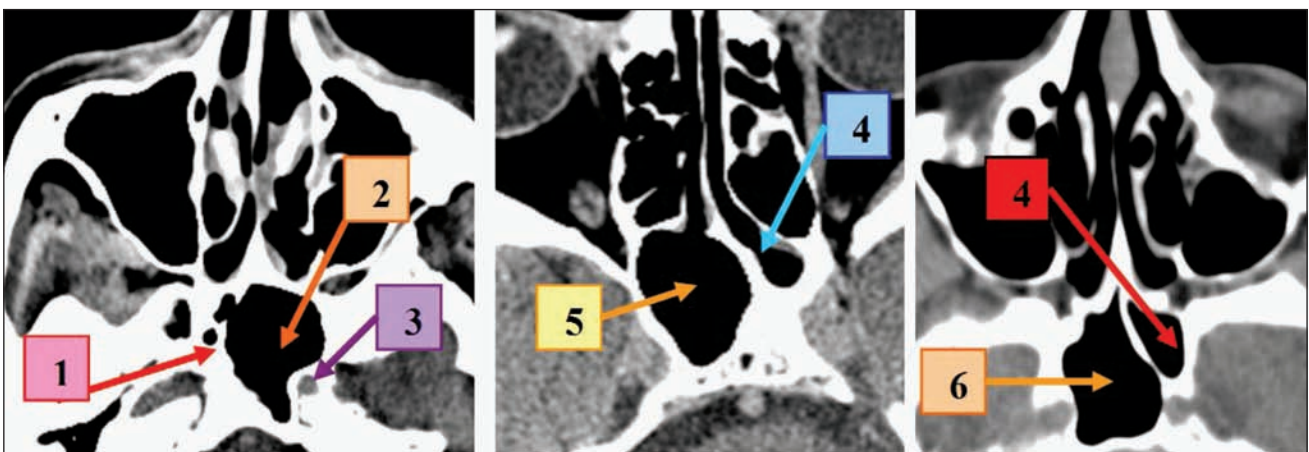


Figure 12 CT scan of the paranasal sinuses, tissue window, axial slices. Conchal pneumatization: 1. Right conchal-type sphenoid sinus reduced to a simple cell; 2. Left selar pneumatization; 3. prociidence of the left internal carotid artery; 4. Hypoplastic left conchal-type sphenoid sinus; 5. Right sphenoid sinus - hypersinus, selar type; 6. Selar-type right sphenoid sinus, lateral wall in contact with both internal carotid arteries (trajectory modification of the left internal carotid artery due to the pneumatization type)

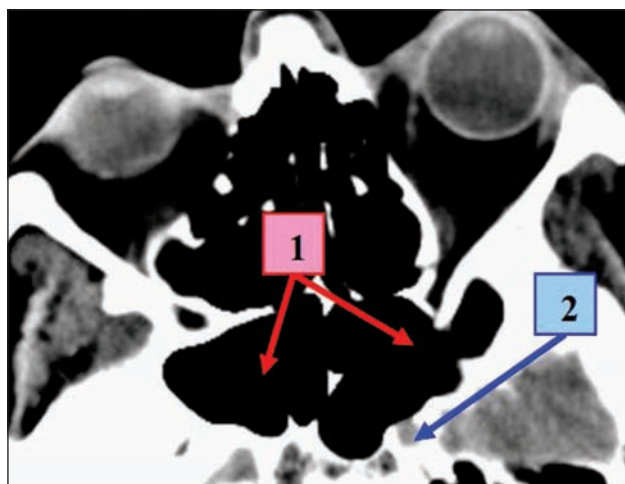


Figure 13 Paranasal sinuses CT scan, bone window, axial slice: 1. Bilateral selar - type pneumatization of the sphenoid sinus (left hypersinus and right pneumosinus dilatans); 2. Dehiscence of the left carotid artery

Table 13
Case distribution according to the hyperpneumatization type

The sphenoidal sinus pneumatization	No. of cases	%
Normal pneumatization	32	64%
Unilateral	13	26%
Right	3	6%
Left	10	20%
Bilateral	5	10%
Total	50	

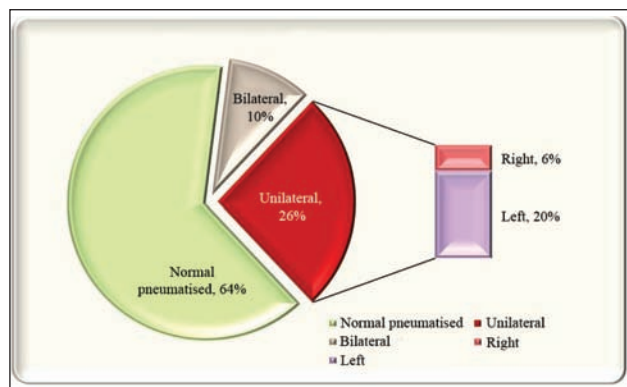


Figure 14 Case distribution according to the hyperpneumatization type

Some authors, including Hamberger CA, Hammer G, Norlen G and collaborators⁹, believe there are 3 types of pneumatization: conchal, preselar, selar. According to these authors, the selar type has a prevalence of 86% (representing a good pneumatization which provides a full indentation of the sella turcica), the preselar type (without indentation, which develops anteriorly in the sella turcica, but in the body of the sphenoid bone, in the anterior part of the tuberculum sellae) with a prevalence of 11%, the remaining being completed by the conchal type and an extremely small number with absence of the sphenoidal sinus. Lang¹⁰ adds to this classification the postselar type, developed posteriorly, beyond the selar indentation. Personal research adheres to Lang’s classification.

The type of pneumatization of the sphenoidal sinus significantly influences sphenoidectomy for access to the pituitary gland. The most common approach for the pituitary adenomas is the endoscopic one. Hamid O., El Fiky L., Hassan O., Kotb A. and El Fiky S.¹⁵ pro-

vide the following values for the types of pneumatization: 2% conchal pneumatization, 21% preselar, 54.7% selar, 22.3% postselar. These authors also found the highest value with the selar type.

Sometimes, inclusion in the four types of pneumatization was more difficult, with borderline aspects: conchal-preselar, selar-preselar, selar-postselar; in this situation we have considered the dominant pneumatization.

Study of the different types of pneumatization of the sphenoid, using Lang’s classification, revealed a global predominance of the selar pneumatization (41/50 cases, prevalence of 82%). In order of frequency, we found the following: the preselar type with 22/50 cases and a prevalence of 44% and the conchal type with 7 cases and a percentage of 14%. The postselar type was found in only one case, with a low prevalence of 2%.

The four types of pneumatization of the sphenoid sinus were evaluated for the left and right sides, including both unilateral and bilateral forms.

The selar type is the most frequent, in accordance with data from the literature studied, both on the right side, with a prevalence of 74%, and on the left side, with a lower percentage of 58%. The second in frequency is the preselar type, with a value of 30% on the left and 22% on the right. The lowest percentages were recorded for the postselar sinus, 1 unilateral case on the left side, with a prevalence of 2%. The conchal form, with 7 cases, had a prevalence of 10% for the left side and 4% for the right.

Making assessments of unilateral and bilateral forms, we found that most bilateral forms (with the same type of pneumatization) were of selar type (25/50) cases, prevalence of 50%, revealing a relatively symmetric expansion of the pneumatization. Bilateral forms were also provided only by the preselar type (4/50 cases, achieving 8%). The remaining types, in 48% of the cases, were with

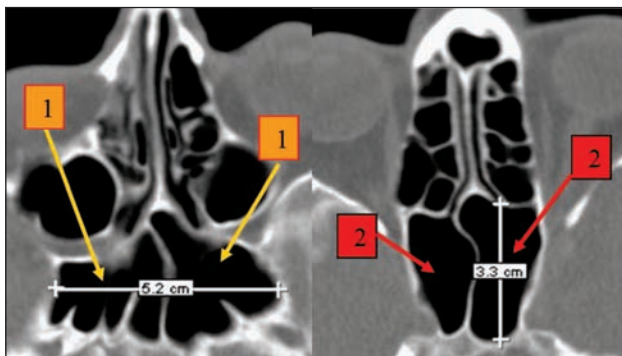


Figure 15 Paranasal sinuses CT scan, axial slices. Sphenoidal hyperpneumatization (lateral and antero-posterior): 1. Bilateral sphenoid sinus pneumatocoele, lateral overgrowth; 2. Bilateral sphenoidal pneumosinus dilatans, with antero-posterior extension

different pneumatization (combinations of the other types of pneumatization). The table with the types of pneumatization of unilateral and bilateral forms shows that there is a great variability, on the left and the right sides; therefore, we can find various combinations of the variants mentioned. Statistical studies revealed a significant association between the type of pneumatization of the sphenoid and its bilateral or unilateral form. Thus, there is a significant association between the selar and the bilateral types (60.98%). In postselar and conchal forms, pneumatization is only unilateral, while in the pre-selar form there are only 18.18% bilateral pneumatizations ($\chi^2=24.4$, $p<<0.05$, 95% CI).

Correlation of the pneumatization type with patients' sex and age shows that there is no significant association between the type of pneumatization of the sphenoid and the patients' sex ($\chi^2=2.54$, $p=0.467$, 95% CI).

By using the ANOVA test in order to investigate if patients' age can be correlated with the pneumatization types, we found no significant differences between patients' average ages depending on the type of pneumatization of the sphenoid ($F=0.24$, $p=0.862$, 95% CI).

Knowing the type of sinus is important in choosing the approach path for the surgery of the hypophysis; for example, the postselar variety is not chosen for the trans-sphenoidal approach of this gland.

2. Sinus hyperpneumatization

Normal pneumatization of the sphenoid sinus can become expansive, extending to the neighbouring structures¹⁶:

1. the vomer, giving the sphenovomerian recess or the sphenovomerian bulla;
2. the ethmoid (more rarely), achieving the anterior recess;
3. towards the maxillary, forming the antero-infero-lateral recess or the maxillary recess of the sphenoid;
4. the palatine bone, in the pterygopalatine fossa;
5. the supraorbital region or the lateral and posterior orbital region (very rarely);

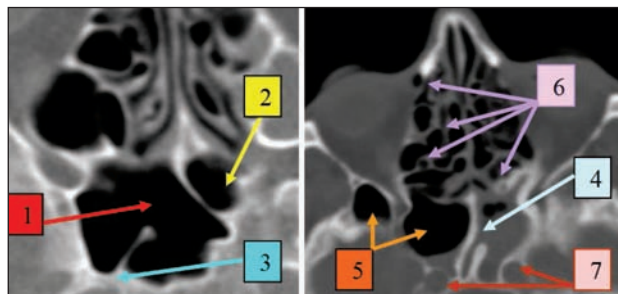


Figure 16 CT scan of the paranasal sinuses, axial slices: 1. Right sphenoid sinus pneumatization (pneumatocoele); 2. Preselar-type small left sinus; 3. Intra-sphenoidal septum inserted into the right internal carotid artery; 4. left sphenoidal pneumosinus dilatans, pathologic process; 5. Pneumatocoele of the right sphenoid sinus, with pterygopalatine extension (pathologic process); 6. Enlargement of the anterior and posterior ethmoidal cells, bilateral (multiple cells); 7. Prolapsing of the internal carotid arteries, in contact with the pathologic process

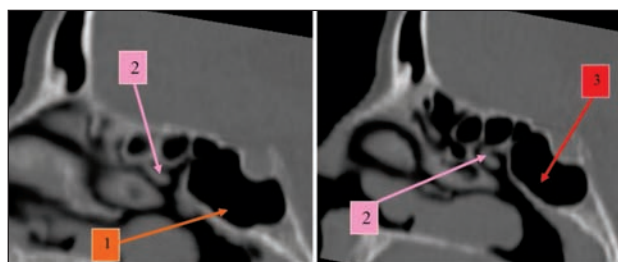


Figure 17 Paranasal sinuses CT scan, right and left sagittal bone reconstruction, through the nasal turbinates. Sphenoidal pneumosinus dilatans - 1. Right; 2. Superior turbinate; 3. Left

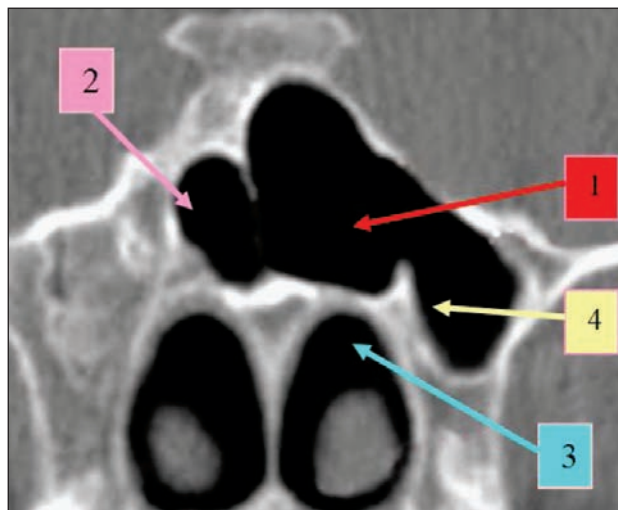


Figure 18 Paranasal sinuses CT scan, coronal reconstruction: 1. Left sphenoid sinus pneumatocoele; 2. Small right sphenoid sinus; 3. Choana; 4. Antero-inferior sphenoidal recess (in the posterior part it merges with the posterior-superior part of the orbit)

6. the lesser or the greater wings of the sphenoid, in lateral direction;
7. the pterygoid process, in infero-lateral direction;

8. basilar process of the occipital bone (the clivus), in posterior direction.

Hyperpneumatization (Figures 19-26) can reach both sphenoid sinuses, only one sinus or part of it. The cause might be a valve phenomenon: the nose blowing, the Valsalva maneuver on a permanent blockage of the sphenoid ostium.

In the studied lot, we identified all forms of extension of pneumatization of the sphenoid sinus to the neighbouring structures. Rare variants found were those with:

- extension to the supraorbital region (2 subjects: one unilateral, the other bilateral);
- extension to the posterior and lateral orbital region (3 subjects: 2 bilateral, one left unilateral);
- antero-infero-lateral extension or maxillary recess of the sphenoid (3 cases).

Moreover, we found, in various degrees of expression, all forms of sphenoidal hyperpneumatization, as they are described by Bell A.F., Ivan D.F., Munson R.A. Barosinus¹², Reicher M.A., Bentson J.R., Halbach V.V., Lufkin R., Hepler R.S.¹³, Marsot-Dupuch Kl, Genty E.¹¹:

1. hypersinus (megasinus);
2. pneumosinus dilatans;
3. pneumocele (pneumatocele).

In a CT radiological study, Earwaker¹⁷ assesses hyperpneumatization of the sphenoid sinus at 12%, before the ethmoid, with 10% and after the maxillary and frontal sinuses, with 15% and, respectively, 63%.

Of all hyperpneumatized sinuses, we selected some axial images (Figure 26) in which we electronically measured the antero-posterior and lateral dimensions of the hyperpneumatized sphenoid sinus.

We evaluated a global prevalence of hyperpneumatization, by correlating it with the pneumatization types, age and sex.

In the 50 studied subjects, we found a normal degree of pneumatization extension in 32 of them, with a prevalence of 64%, while 18 patients had hyperpneumatization in various degrees, with a prevalence of 36%, having all three forms: hypersinus (megasinus), pneumosinus dilatans, pneumatocele (pneumatocele).

Bilateral hyperpneumatization was less common, being identified in 5 cases, with a percentage of 10%, while the unilateral form was more frequent, in 13 cases, achieving a prevalence of 26%. In the unilateral forms the left ones were predominant, 10 cases, with a prevalence of 20%, as compared to the right forms found in only 3 cases, with a prevalence of 6%.

The 18 cases of hyperpneumatization presented different combinations of the three known forms (hypersinus, pneumosinus dilatans, pneumocele), distributed as shown in Figure 27:

The hypersinus dominated the hyperpneumatization forms (11/18/50 cases), with a share of 61.11% of all hyperpneumatizations and achieving a preva-

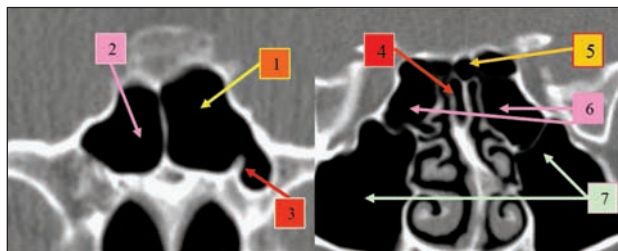


Figure 19 Paranasal sinuses CT scan, bone coronal reconstruction: 1. Left sphenoid hyperpneumatization; 2. normal pneumatization of the right sphenoid sinus; 3. Left pterygoid recess due to the pneumatization of the sphenoid wing (the base of the pterygoid process); 4. Extension of the sphenoid pneumatization to the vomer (median expansion); 5. Crista galli pneumatization; 6. Hyperpneumatization of the posterior ethmoidal cells, bilateral; 7. Hyperpneumatization of both maxillary sinuses

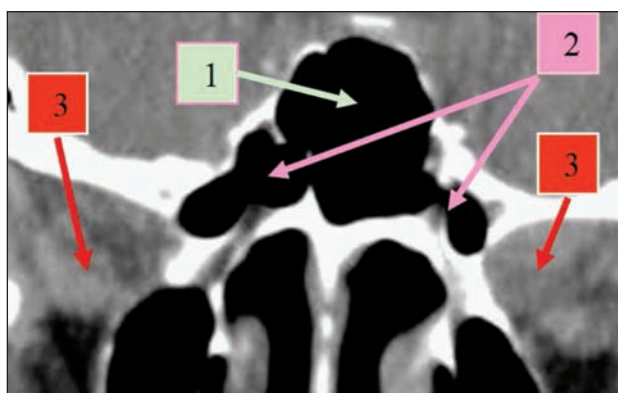


Figure 20 Paranasal sinuses CT scan, coronal reconstruction: 1. Sphenoidal hyperpneumatization (pneumatocele); 2. Bilateral pterygoid recess with pneumatization extension to the supraorbital region; 3. Orbit



Figure 21 Paranasal sinuses CT scan, bone sagittal reconstruction: 1. Sphenoidal hyperpneumatization; 2. Posterior recess extended to clivus and dorsum sellae; 3. Clivus; 4. Rhinopharynx



Figure 22 Paranasal sinuses CT scan, successive bone sagittal reconstruction: 1. Hyperpneumatization of the sphenoid sinus; 2. Anterior sphenoid recess (ethmoid extension, prior to tuberculum sellae)

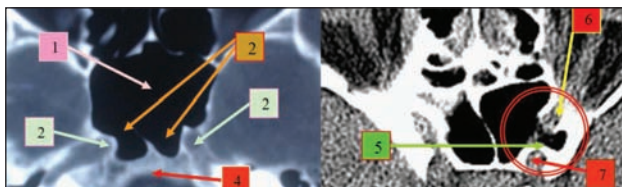


Figure 23 Paranasal sinuses CT scan, bone window, axial slices: 1. Sphenoidal hyperpneumatization (pneumosinus dilatans, absence of the inter-sphenoidal septum); 2. Posterior recesses extended to clivus and dorsum sellae; 3. Prolapsing of internal carotid arteries; 4. Clivus; 5. Left infraoptic recess; 6. Left optic nerve; 7. Left internal carotid artery

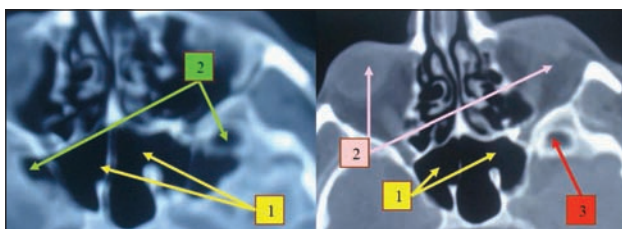


Figure 25 Paranasal sinuses CT scan, bone window, axial slices: 1. Bilateral sphenoid pneumatocele; 2. Lateral pneumatization extension to the pterygopalatine fossa; 3. Pneumatization extension to the postero-lateral part of the left orbit; 4. Orbit

lence of 22%; it is followed by pneumosinus dilatans (5/18/50 cases), the most rare being the pneumocele (pneumatocele), with 2 cases (2/18/50).

The most relevant fact for the endoscopic surgeon in case of hyperpneumatization is to know the extension to functionally and vitally important structures (the internal carotid arteries, the sella turcica, the optic nerves, the branches of the trigeminal nerve, the vidian nerve), the thickness or the dehiscence of the bone that covers them, the anatomical variants that increase the risk of injury.

We have chosen hyperpneumatization for the evaluation because it raises additional problems by modifying the anatomical relationships of the sphenoid with the neighbouring structures traditionally described: the internal carotid artery on its intracavernous trajectory, the optic nerve, the maxillary nerve, the vidian nerve, the posterior ethmoid.

Figure 28 reveals a case of bilateral sphenoidal hyperpneumatization with extension in all directions, predominantly on the right, with thin, demineralized walls (pneumatocele). Excessive lateral overgrowth modifies the boundaries and the anatomical relationships of the pterygo-palatine fossa, an important aspect for the approach of the included structures (the vidian nerve, the speno-palatine artery, the maxillary nerve, the speno-palatine ganglion). Also, modifies the distance between the internal carotid arteries, the relation to the lateral wall, the degree of indentation in the sinus (prolapsing, dehiscence occur more frequently). In this patient, the right internal carotid ar-

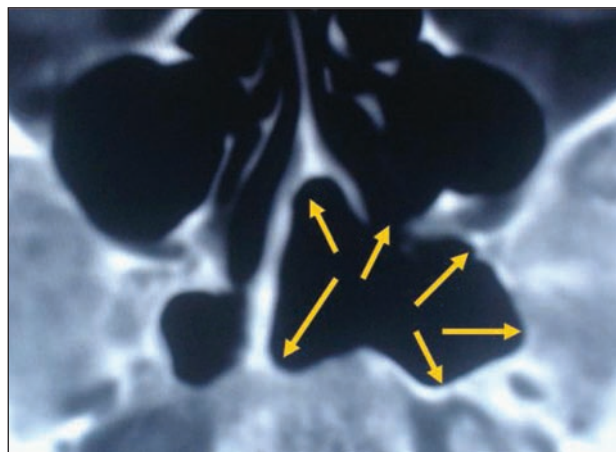


Figure 24 Paranasal sinuses CT scan, bone window, axial slice. Extended left sphenoid sinus pneumatization: posterior - to clivus and dorsum sellae; lateral - sphenoid great wing, pterygoid process; anterior - posterior ethmoid cells; antero-infero-lateral - maxillary sinus (the arrows point the extension directions)

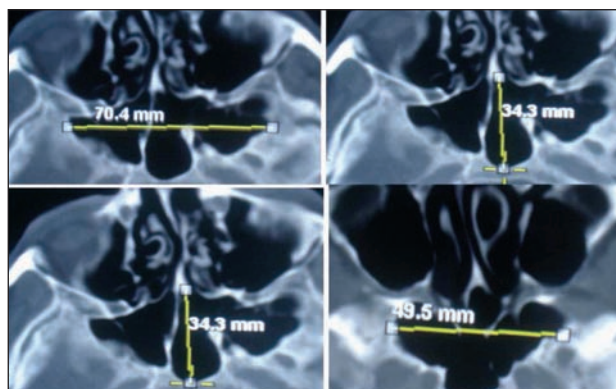


Figure 26 Paranasal sinuses CT scan, bone window, axial slices. Measured hyperpneumatized sphenoid sinuses

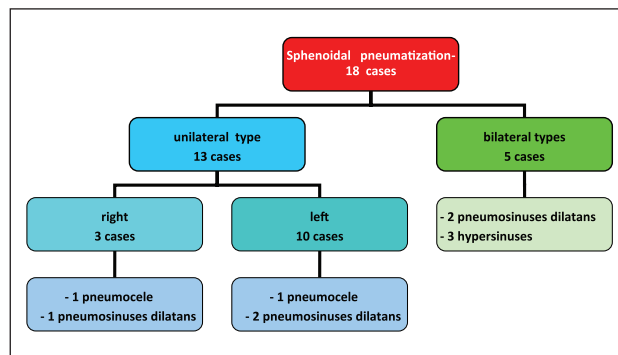


Figure 27 Cases distribution by type and location (unilateral/bilateral) of the sphenoidal hyperpneumatization

tery is in relation to the posterior wall and not to the lateral one, as it is traditionally described. The optic canal is clearly right intrasinusal (surrounded by airy space). Due to excessive pneumatization of the ptery-

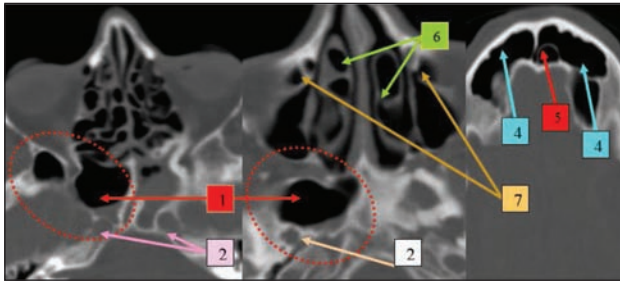


Figure 28 Paranasal sinuses CT scan, bone window, axial slices. Sphenoid sinus hyperpneumatization (right pneumatocele and left hypersinus associated with extrasinusal pneumatization): 1. Right sphenoid sinus pneumatocele due to right excessive extension and changes of the sphenopalatine fossa limits; 2. Bilateral prolapsing of the internal carotid artery; 3. Right internal carotid artery in contact with the posterior wall of the sphenoid sinus and not with the lateral one; 4. Bilateral hyperpneumatization of the frontal sinus; 5. Kuhn IV cell; 6. Bilateral concha bullosa; 7. Haller cells (bilocular - right, unilocular - left)

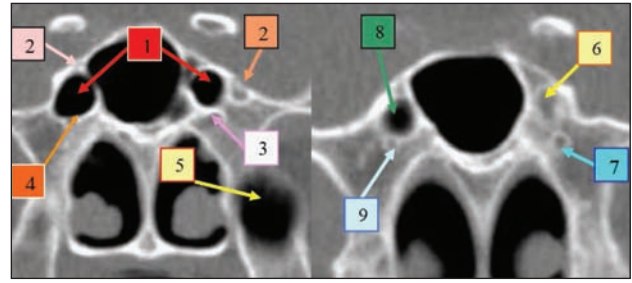


Figure 29 Paranasal sinuses CT scan, coronal bone reconstruction. Lateral (lateral recess) and inferior (to the maxillary sinus) extension of the sphenoid sinus pneumatization with changing the distances pterygoid foramen - round foramen: 1. Bilateral lateral recess; 2. Foramen rotundum; 3. Pterygoid foramen for the left vidian nerve; 4. Pterygoid foramen for the right vidian nerve; 5. Left maxillary sinus. Lateral sphenoid sinus pneumatization extension with a small right recess; 6. Left foramen rotundum; 7. Pterygoid foramen for the left vidian nerve; 8. Small right side lateral recess; 9. Right pterygoid foramen

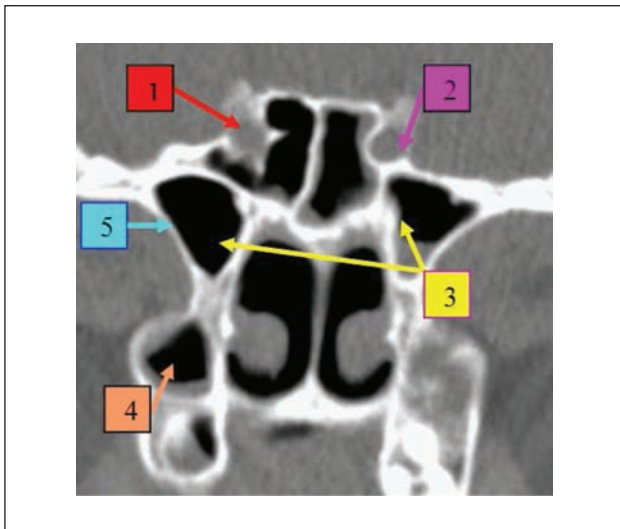


Figure 30 Paranasal sinuses CT scan, bone window, coronal slice. Bilateral sphenoid excessive hyperpneumatization (pneumatocele, probably with a satellite pathologic tumoral process onset in the right cavernous sinus): 1. Right internal carotid artery protrusion with the intrusion of the wall; 2. Prolapsing of the left internal carotid artery, surrounded by a sinus inflammatory process; 3. Inferior and lateral extension of the pneumatization to the supero-internal part of the orbit, with left pathologic process; 4. Right maxillary sinus; 5. Posterior and superior part of the right orbit

goid process, the relationships of the pterygo-palatine fossa are also modified. The case associates: hyperpneumatization of the frontal sinuses, left Kuhn IV cell, widening of the anterior and posterior ethmoids containing many cells, extensive bilateral concha bullosa with 3 cells on the left, bilateral Haller cells. Excessive sphenoidal pneumatization requires differential diagnosis of an anatomical variant (minor anomaly) with a pathological situation, usually a tumor. Imaging presented reveals a pathological process in both sphenoid sinuses, with liquid level on the right side and quasi-

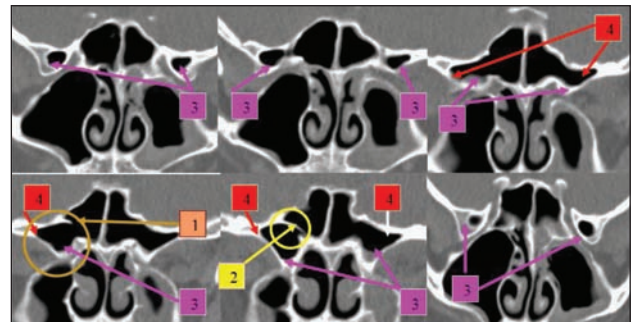


Figure 31 Paranasal sinuses CT scan, successive axial slices. Lateral extension of the sphenoid sinus pneumatization (lateral-inferior recess and pterygoid recess). 1. Infero-lateral recess communicating with the pterygoid recess; 2. Intra-sinusal right vidian nerve, in the lateral recess; 3. Bilateral pterygoid recess; 4. Infero-lateral recess

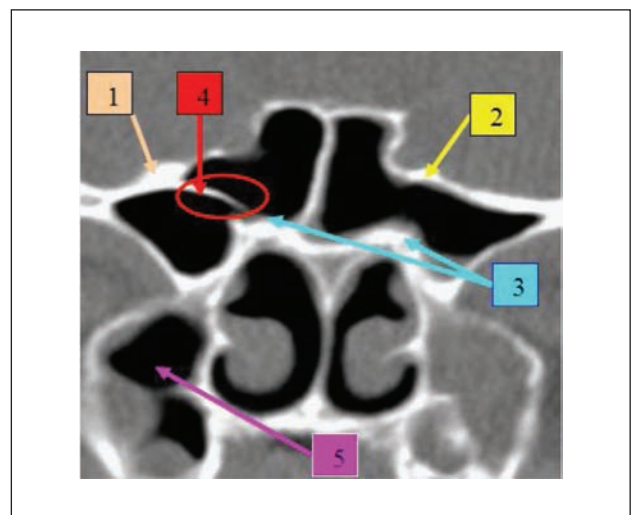


Figure 32 Cranio-facial CT scan, coronal bone reconstruction. Bilateral sphenoidal hyperpneumatization: 1. Left foramen rotundum; 2. Right foramen rotundum; 3. Pterygoid foramen for the left and right vidian nerve; 4. Intra-sphenoidal trajectory of the right vidian nerve, lateral recess level (pterygoid recess); 5. Right maxillary sinus

total occupation on the left side. Rigorous evaluation requires CT scan with contrast substance and MRI.

An excessive pneumatization with thickness modification, demineralization and sinus walls erosion (pneumocele) may lead to major asymmetries in the lateral expansion of the sinus, by increasing the distance between the vidian canal and the round hole, as well as intrasinus exposure of the vidian or maxillary nerves. This anatomical variant must be known in sphenoidectomies, in hypophysis approach¹⁸, but especially in the surgery of the pterygo-palatine fossa.

If extension of the pneumatization is lateral (inferior lateral recess), the distance between the round foramen and the pterygoid canal foramen for the vidian nerve modifies, which is important to know when approaching it (the "crocodile tears" syndrome). This nerve can protrude into the pterygoid recess wall or it can have an intrasinus trajectory in the same recess (anatomical variant with risk of injury of the nerve in sphenoidectomies). Figure 29 shows the variable relationships of the pterygoid canal foramen with the round foramen, depending on the sphenoid sinus pneumatization.

As Earwaker¹⁷ states, hyperpneumatization with extension of the sinuses beyond the boundaries of the convex walls may not be an anatomical variant, but a satellite appearance of a tumoral lesion, usually meningioma. The normal/pathological limit is worth knowing. Such a situation is revealed in Figure 30: excessive hyperpneumatization of the sphenoid sinuses with protrusion of both internal carotid arteries. Sinus volume growth is primarily due to the bilateral lateral recess (the pterygoid recess, which extends to the superior wall of the orbit, on its internal side, and the inferior lateral recess). Successive sections in Figure 32 show that the inferior lateral recess continues with the pterygoid recess, where, on its right side, the vidian nerve is intrasinus (Figures 30-32). The images show a right internal carotid artery with intrusion of the intrasinus wall, suggestive for a tumoral process (astrocytoma, meningioma), imposing MRI and examination with contrast substance.

CONCLUSIONS

1. The most frequent type of sphenoidal pneumatization (Lang's classification) is the selar one, both in the right sinuses (74%), and in the left ones (58%), followed by the preselar, conchal and postselar variety.

2. There is no significant association between the type of sphenoidal pneumatization and patients' sex ($\chi^2=2.54$, $p=0.467$, 95% CI), or major differences between patients' average ages, depending on the type of pneumatization of the sphenoid ($F=0.24$, $p=0.862$, 95% CI).

3. Hyperpneumatization had a prevalence of 61.11%, the hypersinus having the highest percentage (22%), followed by pneumosinus dilatans and pneumocele.

4. Unilateral hyperpneumatization was dominant (72.22% of all hyperpneumatizations), with a global prevalence of 26%, versus the bilateral one, with 10%.

5. Hyperpneumatization might be an anatomical variant or a satellite phenomenon of a tumoral disease.

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