Anatomical Variations of the Frontal Sinus

Variaciones Anatómicas del Seno Frontal

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SUMMARY: An anatomical study of the frontal sinus in 100 macerated skulls. The study introduces an innovation on the literature by means of the measurement of the sinus's volume. All the found information in the literature attained to other aspects including the diameters of the sinus and the geometric area of the same. Objective: Evaluation of the measures of the frontal sinus frequently involved in cranial base surgeries and supraorbital craniotomies in order to help the surgical approaches that cross this anatomical route. Methods: The measurement included: sagittal, transverse and antero-posterior diameter acquired with a paquimeter and the volume obtained after filling the sinus with sand. Results: They are in accordance with the literature that shows the male's predominance in all measurements done.

KEY WORDS: Frontal sinus; Supraorbital craniotomy; Paranasal sinus.

INTRODUCTION

The minimally invasive surgeries have acquired a growing importance in surgical interventions in order to avoid tissue damage and reduce surgical time.

In neurosurgery, the number of publications concerning these kind of approaches has also increased (Fukushima *et al.*, 1991; Menovsky *et al.*, 1999; Perneczky *et al.*, 1993; Steiger *et al.*, 2001; Taniguchi & Perneczky, 1997). When cranial base surgery is made in the frontal region or when the supraorbital mini-craniotomy is realized, the involvement of the frontal sinus may become troublesome. The entrance by means of the craniotomy in the frontal sinus can lead to postoperative complications as CSF leakage, bone flap infections, besides the late consequences of meningitis and brain abscess.

The frontal sinuses are two, situated in the posterior part of the superciliary arcs, between the external and internal faces of the frontal bone. They are seldom symmetrical; generally, there is a septum between both, which usually deviates from the midline. They point upwards beyond the middle part of the supercilious and backwards to the medial part of the orbital roof. The sinuses are divided into several recesses, which communicate with each other through incomplete bony septa. Occasionally, one or both sinuses may be absent. The prominence of superciliary arcs does not

indicate the absence, presence or size of the frontal sinus. The extension upwards beyond the frontal bone may be a small one, while the orbital part may be bigger. In some cases, a sinus may be overlapping in front of the other one. Each one opens into the corresponding medium meatus of the nose, through the ethmoidal infundibulum of the frontonasal duct, and crosses the anterior part of the ethmoidal labyrinth.

The blood supply originates from the ethmoidal and supraorbital arteries, and the venous drainage takes place at the anastomotic vein located in the supraorbital notch, binding the supraorbital and superior ophthalmic veins. The lymphatic drainage is directed towards the submandibular lymphonodi. The area is innervated by the supraorbital nerve, a branch of the frontal nerve of the first trigeminal division.

MATERIAL AND METHOD

One hundred macerated skulls were randomly assigned for evaluation after section on axial plane 1 inch above the superciliary arcs (Fig. 1).

The measures of anteroposterior, sagittal and transversal diameters were taken. The presence or absence of the

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metopic suture were assigned. With bone-wax, the frontonasal ducts were occluded bilaterally. A syringe with fine sand was utilized to fill completely the frontal sinus and then the amount of sand necessary to complete this was quantified, verifying the volume that left the syringe. With this measure we had the approximate volume of the sinus.

Fig. 1. Macerated skull. Section on axial plane 1 inch above the superciliary arcs.

RESULTS

The distribution by sex is described in the tables below, followed by the location of the sinuses observed in the sample (Tables I and II). The frontal sinus was present in 75.3% of the cases and absent in 24.3%. The metopic suture was absent in almost 63% (Table III) of the cases and there was no correlation between this occurrence and the frontal sinus presence.

The results obtained with measures were the following ones summarized in Table VI. The mean age was 63.55 years, with a minimal of 22 and a maximum 95 and a standard deviation of 18.20.

The average volume of the sinuses measured with sand was 10.25, with a minimal value of 1.1 and maximal of

38 and a standard deviation of 7.15. The mean antero-posterior diameter was 7.849 mm, with a minimum value of 3.1 mm and a maximum 18 mm with a standard deviation of 2.91mm. The mean transversal diameter was 40.59 mm, with a minimum of 4mm and a maximum of 96 mm and of standard deviation 21.96 mm. The median sagital diameter was 33.40 mm, with a minimum of 11 mm and maximum 75 mm.

The statistical analyses demonstrated a significant difference concerning gender and location of the sinus with predominance of the left side in males (Table IV and V).

The measures showed difference related to gender in all analyzed diameters in favor of males (Table VI). The independent sample analyses failed to demonstrate any statistical significance in taken measures but there was a trend of greatest difference in transversal diameter between genders (Table VII).

DISCUSSION

Andreas Vesalius is considered by many scholars as the father of the Anatomy. He described the frontal sinus in his famous book “*Di Humani Corporis Fabrica*”, as a cave full of air. Falopius, one of Vesalio’s pupil, has detailed the sinus referring to their absence in newborns. Blaney (2000) reports that the frontal sinuses are anatomical structures only found in the human being and in some large African apes. Such facts draw the attention to the anatomical similarities between both species.

Schuller (1943) has verified in radiological studies that the frontal sinuses are quite bigger in males than in females, and emphasized that the presence of metopic suture is associated with absence of the frontal sinuses.

Libersa & Faber (1957) have observed that the frontal sinus usually appear in the third year of life. Krogman (1962) reports that the frontal sinus become an extension of the nasal cavity after the second year of life and grows progressively until the age of 20 years.

Porbonikova (1974) carried out a study with 720 X-ray pictures in 1 to 13 years old children by evaluating the frontal sinus growth. She observed that growth begins on the thirteenth month of age, being the same in both sexes, and goes on up to the age of 20 years when the parameters start diverging in girls who display a horizontal sinus enlargement while boys show a vertical enlargement of the sinuses. Apart this, she observed a larger growth of the left sinus when compared to the right one.

Table I. Distribution by sex of the location of the frontal sinuses.

	Frequency	Percent	Valid percent	Cumulative percent
Male	45	45	45	45
Female	55	55	55	100
Total	100	100	100	

Table II. Location of the frontal sinuses.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Absent	24	24.0	24.7	24.7
	Left	27	27.0	27.8	52.6
	Right	20	20.0	20.6	73.2
	Central	26	26.0	26.8	100.0
	Total	97	97.0	100.0	
Missing	System	3	3.0		
Total		100	100.0		

Table III. Metopic suture.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Absent	61	61.0	62.9	62.9
	Present	36	36.0	37.1	100.0
	Total	97	97.0	100.0	
Missing	System	3	3.0		
Total		100	100.0		

Table IV. Crosstabulation. Sex.

			Situation	Total	
			Left	Right	
Sex	Male	Count	16	6	22
		% within gender	72.7	27.3	100.0
	Female	Count	11	14	25
		% within gender	44.0	56.0	100.0
Total		Count	27	20	47
		% within gender	57.4	42.6	100.0

Table V. Chi-square test. a Computed only for a 2x2 table. b 0 cells (0%) have expected count less than 5.

	Value	df	Asymp. sig. (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)
Pearson Chi-square	3.951	1	0.047		
Continuity correction	2.863	1	0.091		
Likelihood ratio	4.031	1	0.045		
Fisher's exact test				0.076	0.045
Linear-by-linear association	3.866	1	0.049		
N° of valid cases	47				

Table VI. T - test

Group Statistics	Gender	n	Mean	Std. deviation	Std. error mean
Volume	Male	34	11.875	5.957	1.0216
	Female	39	10.1492	8.0401	1.2874
Antero-posterior diameter	Male	34	8.0265	2.7192	0.4663
	Female	39	7.9718	3.104	0.497
Transversal diameter	Male	34	44.5985	22.6357	3.882
	Female	39	37.9128	21.1621	3.3886
Sagital diameter	Male	34	36.6382	10.4821	1.7977
	Female	39	33.5467	11.7744	1.8854

Table VII. Independent sample test

	Levene's Test for equality of variances		t-test for equality of means		Sig. (2-tailed)	Mean difference	Std. Error difference	95% Confidence interval of the difference	
	F	Sig.	t	df				Lower	Upper
Volume									
Equal variances	0.69	0.409	1.029	71	0.307	1.7258	1.6771	-1.6183	5.0698
Equal variances not			1.05	69.288	0.297	1.7258	1.6435	-1.5527	5.0043
Antero-posterior									
Equal variances	0.74	0.394	0.079	71	0.937	5.47E-02	0.6878	-1.3168	1.4261
Equal variances not			0.08	70.997	0.936	5.47E-02	0.6816	-1.3043	1.4137
Transversal diameter									
Equal variances	0.18	0.672	1.304	71	0.197	6.6857	5.1289	-3.5411	16.912
Equal variances not			1.297	68.109	0.199	6.6857	5.1529	-3.5965	16.967
Sagital diameter									
Equal variances	0.44	0.508	1.177	71	0.243	3.0916	2.6261	-2.1447	8.3279
Equal variances not			1.187	70.963	0.239	3.0916	2.6051	-2.1028	8.286

Szilvassy (1981) studied the variability of the frontal sinus in children and young people aged between 3 and 7 years, in 215 children. He observed that between the age 8 to 12 years, the growth rate of male frontal sinus is a very low one. Between the age 14 to 15 years, male frontal sinuses exceed female ones, where size is concerned, so we can conclude that a complete formation of the sinuses takes place at the age of 18.

The measures of diameters have all been significantly higher in males than in females according the literature

(Blaney; Hanson & Owsley, 1980; Libersa & Faber; Pondé *et al.*, 2003; Porbonikova; Szilvassy), though none of these authors had ever measured the antero-posterior neither the volume, only the area of the sinuses. Ponde found a significantly higher antero-posterior diameter when comparing both genders ($p < 0.001$) in a study with computer tomography (Pondé *et al.*).

Brown *et al.* (1984) have found in a simple X-ray study that the sagital diameter is significantly larger in males. They have found an average of 32.6 mm in males against

26.6 mm in females. In a similar work, Harris *et al.* (1987) have found a height of 30.1 mm in males against 26.0 mm in females. Pondé *et al.* have found that the sagittal diameters were significantly higher in males ($p < 0.04$).

Porbonikova reports that females have a proportionally larger frontal sinuses than males, when compared to the sagittal diameter, which is much larger in males. She justifies this finding as being due to a more homogeneous growing of frontal sinuses in females if compared with sinus growth in males. Pondé found measures of 58.3 mm and 46.9 mm in males and females respectively, but without statistical significance ($p < 0.10$).

Harris *et al.* has found such measures as 58.3 mm in males and 46.9 mm in females. In the total sum of measures, it was possible to verify that the frontal sinuses of males

showed a quite higher development than those of females ($p < 0.01$) according others authors (Krogman; Menovsky *et al.*, 1999; Phrabhakaran *et al.*, 1999; Schuller). Pondé *et al.* have emphasized the antero-posterior diameter as the most important contribution for the significant increase of volume in the male's sinuses when compared with females (Pondé *et al.*).

What regards the absent frontal sinus, Krogman has observed its absence in 5% adults, while Gulisano *et al.* (1978) observed its absence in 4.8% of the cases. We observed 24.7% of frontal sinus missing with 20.8% in males and 27.9% in females. Gulisano *et al.* has also observed that the left sinus tends to be larger than the right one, a fact that could be observed by Pondé *et al.* though they had not found any difference between the genders and within the sample itself.

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RESUMEN: Se presenta un estudio anatómico del seno frontal que fue realizado en 100 cráneos. El estudio introduce una novedad en la literatura, que es la medida volumétrica del seno frontal. Toda la literatura se refiere a otros aspectos, incluyendo los diámetros de los senos y su área geométrica. El objetivo del estudio fue estimar las medidas del seno frontal que con frecuencia hacen parte en las cirugías de la base del cráneo y en las craneotomías supraorbitarias, con la finalidad de facilitar las vías de acceso quirúrgico por estas regiones. Las medidas realizadas fueron: diámetro sagital, transversal y antero-posterior con un caliper, y el volumen fue obtenido llenando el seno con arena fina. Los resultados están de acuerdo con la literatura que demuestra un mayor predominio del sexo masculino en todas las medidas efectuadas.

PALABRAS CLAVE: Seno frontal; Craneotomía supraorbitaria; Seno paranasal.

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