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Study of Anatomical Variations of the Frontal Sinus by Computed Tomography Scans of Egyptians

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ABSTRACT

Background: A great interest has been paid toward the anatomic variations of frontal sinus (FS) and frontal recess (FR). The international frontal sinus anatomy classification (IFAC) has by time attained a growing popularity being a novel and simple classification of frontal recess cells (FRCs).

Objective: This study aimed to provide better understanding of FS morphometry and anatomic variations of FRCs and their prevalence among Egyptian adults using computed tomography (CT). **Patients and methods:** We enrolled 500 adult Egyptian patients in this study. The medical records and CT studies of the cases were reviewed to assess their demographic data and the pattern of frontal sinus as appeared in the radiological findings. Frontal sinus classification was described using the IFAC.

Results: Regarding the IFAC, agger nasi cells (ANCs) were found in 97.8%, supra agger cells (SACs) in 50.4%, supra Agger frontal cells (SAFCs) in 24%, supra bulla cells (SBCs) in 87.8%, supra bulla frontal cells (SBFCs) in 26.2%, supraorbital ethmoidal cells (SOECs) in 9.4% and frontal septal cells (FSCs) in 27.6% of cases. Regarding the frontal sinus's size, aplasia was detected in 11 cases (2.2%), hypoplasia in 36 cases (7.2%) and hyperplasia in 105 (21%), while the large percent of the cases had medium sized sinuses (69.6%). **Conclusion:** ANCs were the most prevalent cells. Occurrence of IFAC cells was closely related to that found in our study. High-resolution CT scans can delineate the FRCs, which is important for preoperative assessment and treatment of pathologies related to the FS.

Keywords: Computed tomography, Anatomical variations, Frontal sinus.

INTRODUCTION

Frontal sinuses are a pair of pneumatic cavities that start to develop at the 4th intrauterine and continue up till the age of 20. They are always asymmetrical and separated by a septum and they pneumatize into the orbital plate of frontal bone [1]. Their location (behind and above the frontal beak) requires an angulated endoscope. Therefore, it is challenging to approach them surgically. Incomplete clearance of the frontal sinus drainage pathway (FSDP) during the endoscopic frontal sinus surgery (EFSS) is a common cause of EFSS's failure in chronic rhinosinusitis [2]. The EFSS often fails when there is inadequate removal of FRCs, miss identification of the frontal sinus ostium (FSO), recurrent mucosal diseases and iatrogenic FR injury [3]. These previously-mentioned have either a direct or an indirect relation to FRCs and their orientation and configuration in the FR alongside with their relation to the FSO and neighboring structures [4]. To avoid complications or EFSS's failure, surgeons should better understand the anatomy to draft an appropriate surgical approach that allows proper preparation and accurate placement of instruments. This would also enable adequate clearance of the FR and FSO [5].

Several classifications aim to classify different frontal cells. On the other hand, a system that addresses the number and position of FRCs and their effects on the FSDP can help understand the surgical anatomy and surgical approaches [6]. The IFAC has by time attained a growing popularity being a novel and well-defined classification of FRCs. Based on IFAC, FRCs are classified into anterior, posterior, and medial cells [7].

This study aimed at providing better understanding of FS morphometry and anatomic variations of FRCs and their prevalence among Egyptian adults using CT scans. This in turn would highlight the risks and safety of FS surgery.

PATIENTS AND METHODS

This retrospective study included a total of 500 Egyptian adult patients (aged > 18 years) who had CT scans on their heads, for different reasons other than FS pathologies, at The Otorhinolaryngology and Radiology Departments at Mansoura University Hospitals throughout a period of 12 months.

Exclusion criteria: Cases with sinusitis (opacifications, air-fluid level, and/or mucosal thickening > 3 mm in the FS), prior FS surgery, sinonasal pathology, maxillofacial deformity or fractures, and cases with incomplete records were not included.

The medical records were reviewed to obtain the following data:

Radiological examination by CT scan was performed at the Radiology Department. A multislice CT scanner (Philips, Ingenuity, Best, Netherlands) was used and no contrast agent was injected during the scan. The patient was examined in supine position with a standard helical CT scanning of the nose and paranasal sinuses (120 Kv, 200 MAs section collimation 0.6 mm). Row data were reconstructed using sharp and thin cuts in axial and coronal planes. Two archives were utilized to collect data; a hard archive (CT films) obtained from the Otolaryngology Department (40% of cases) and an electronic archive (CT scans in Dicom files) from the Radiology Department (60% of cases). The Radiant

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Dicom viewer (32-bit) software was used to review the electronic archive.

Radiological measurements included width, height, and depth of the right and left sinuses. The border lines the FS were determined. The separation between the left and right sinuses was based on the septum between both. The greatest height, width and depth of each sinus underwent calculation from the maximum distance from the FS base to the upper line, the maximum distance between the medial and lateral lines and from the maximum distance from anterior line to the posterior line correspondingly. The height and width were measured on coronal plane whereas the depth was measured on sagittal plane. The sinus volume was calculated (height X width X depth). The IFAC described by **Wormald *et al.*** [7] was applied on our included patients. According to Bent and Kuhn classification, the right and left sinuses were classified into 4 types: I, II, III and IV FRCs. A cell with complete walls was considered as a cell, whereas that with incomplete walls was considered as septation.

Ethical considerations: The study was done after being accepted by The Research Ethics Committee, Mansoura University (Code: MS.22.06.2022). All patients provided written informed consents prior to their enrolment. The consent form explicitly outlined their agreement to participate in the study and for the publication of data, ensuring they were fully informed about the study's purpose, procedures, and potential risks as well as ensuring protection of their confidentiality and privacy. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis: Results were statistically analysed with the SPSS version 22.0 software (IBM/SPSS Inc., Chicago, IL). Continuous data were represented as means ± SDs/ medians (ranges) while frequencies with percentages were utilized to present qualitative data.

RESULTS

This study included 500 Egyptian adult patients who were recruited from Otorhinolaryngology and Radiology Department, Faculty of Medicine, Mansoura University. They underwent CT scanning of the head for any reason but not FS pathology. The mean age was 43.9 ± 11.54 years, the median age was 41 years (range =29 - 72 years). There were 278 men (55.6%) and 222 women (44.4%) (Table 1).

Table (1): Demographics of the study cases (n=500)

Variables	Study cases (Number = 500)	
Sex:	**Number**	**%**
Men	**278**	**55.6**
Women	**222**	**44.4**
Age:		
Mean ± SD	**43.9 ± 11.54 years**	
Median (Range)	**41 years (29 - 72 years)**	

SD: standard deviation.

As regards the FS size, aplasia was detected in 11 cases (2.2%), hypoplasia in 36 cases (7.2%) and hyperplasia in 105 (21%) while the large percent of the cases had medium sized sinuses (69.6%) (Table 2).

Table (2): Anatomical variations of the FS (according to size) in the study cases (n=500)

	Study cases (Number = 500)	
Medium sized frontal sinus	348 cases	69.6%
Frontal sinus aplasia	11 cases	2.2%
Frontal sinus hypoplasia	36 cases	7.2%
Frontal sinus hyperplasia	105 cases	21%

Categorical data expressed as Number (%)

According to the international frontal sinus classification, ANCs were found in 97.8% of cases, SACs in 50.4%, SAFCs in 24% of the cases, SBCs in 87.8% of the cases, SBFCs in 26.2% of the cases, SOECs in 9.4%, and FSCs in 27.6% (Table 3).

Table (3): International frontal sinus classification of the study cases (n=500)

Variables	Study cases (Number = 500)	
Agger nasi cell	**Number**	**%**
Present	٤٨٩	97.8
Absent	11	2.2
• **Absent unilateral**	4	0.8
• **Absent bilateral**	7	1.4
Supra agger cell	**N**	**%**
Present	252	50.4
Absent	248	49.6
• **Absent unilateral**	103	20.6
• **Absent bilateral**	145	29
Supra Agger frontal cell	**N**	**%**
Present	120	24
Absent	380	76
• **Absent unilateral**	163	32.6
• **Absent bilateral**	217	43.4
Supra bulla cell	**N**	**%**
Present	439	87.8
Absent	61	12.2
• **Absent unilateral**	25	5
• **Absent bilateral**	36	7.2
Supra bulla frontal cell	**N**	**%**
Present	131	26.2
Absent	369	73.8
• **Absent unilateral**	172	34.4
• **Absent bilateral**	197	39.4
Supraorbital ethmoidal cell	**N**	**%**
Present	47	٩.4
Absent	453	90.6
• **Absent unilateral**	172	34.4
• **Absent bilateral**	281	65.6
Interfrontal septal cell	**N**	**%**
Present	138	27.6
Absent	362	72.4
• **Absent unilateral**	159	31.8
• **Absent bilateral**	203	40.6

Based on the Bent and Kuhn classification, type 1 cells were found in 129 cases (25.8%), type 2 cells in 224 cases (44.8%), type 3 cells in 105 cases (21%) and type 4 cells in 42 cases (8.4%) (Table 4).

Table (4): Bent and Kuhn classification of the study cases (n=500)

Variables	**Study cases (Number = 500)**	
	N	**%**
Type 1	129	25.8
Type 2	224	44.8
Type 3	105	21
Type 4	42	8.4

Categorical data expressed as Number (%).

CASE PRESENTATION

International Frontal Sinus Anatomy Classification:

(1) Supra bulla frontal cell: It originates in the supra-bulla region and pneumatizes along the base of the skull into the posterior part of the FS. The base of skull forms its posterior wall.

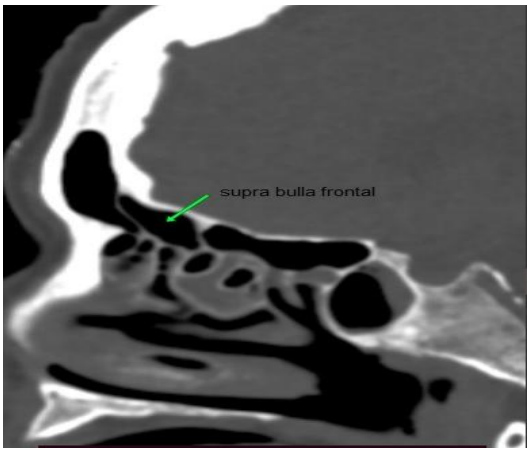

Figure (1): Supra bulla frontal cell (Sagittal cut).

Bent and Kuhn Classification

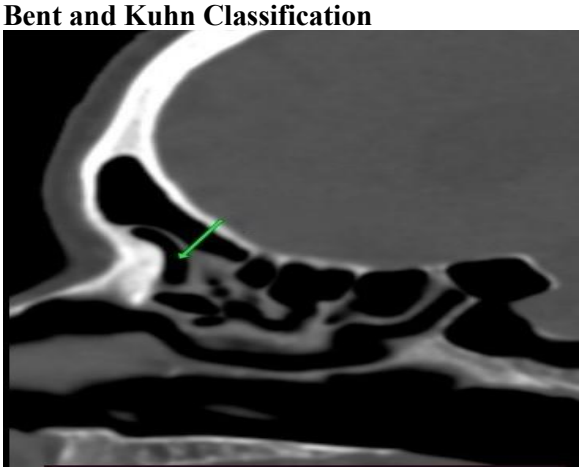

Figure (2): Type 3: At least 1 cell protrudes into the FS.

Frontal sinus sizes (3).

Figure (3): Medium-sized: pneumatization on the supraorbital line and medial to the mid-orbital line.

DISCUSSION

In our study and based on the IFCC, ANCs were present in 97.8% of cases, SACs in 50.4%, SAFCs in 24%, SBCs in 87.8%, SBFCs in 26.2%, SOECs in 9.4% and FSCs in 27.6% of cases. Our findings are consistent with **Oraby *et al.*** [8] who studied 60 cases reporting that ANCs were found in 95% of cases, SACs in 40.8%, SAFCs in 13.3%, SBCs in 61.7%, SBFCs in 27.5%, SOECs in 14.2% and FSCs in 23.3% of cases. Our results also agree with **Nofal and El-Anwar** [4] who included 100 patients (200 sides). They showed that the anterior group cells were the commonest cells (n=312 cells). The ANCs were the commonest cells as they were found in 97% of cases, the SACs were found in 48% of cases, while the SAFCs were found in only in 11% of cases. They also showed that the number of posterior group cells was 274. The SBCs were the commonest cells reported in 72% of cases, the SBFCs were the least presented, found in 23% of cases, the SOECs were present in 42% of cases and the FSCs existed in 21% of cases. Moreover, **Fawzi *et al.*** [9] demonstrated that among all frontal cell variations on 200 cases, ANCs were the commonest (95.5%) followed by SBCs (60.8%), SBFCs (53.0%), SACs (50.0%), SAFCs (36.0%), FSCs (8.3%), and SOECs (5.5%). In the study by **Tran *et al.*** [10], ANCs were present in 95.7% of cases, SACs in 16.3%, SAFCs in 13%, SBCs in 46.2%, SBFCs in 4.3%, SOECs in 17.3%, and FSCs in 10.6%. **Choby *et al.*** [11] also reported that ANCs were the commonest type of anterior group cells (91.9%), followed by SACs (28.7%) and SAFCs (15.9%). SBCs were the most common type of posterior group cells (59.7%) followed by SBFCs (25.8%) and SOECs (6.9%). FSCs were present in 14.3% of cases. **Johari *et al.*** [5] examined 312 sides from 156 CT scans. ANCs were found in 98.1% of cases, frontal ethmoidal cell types 1, 2, 3 and 4 were found in 28.8%, 31.1%, 14.4% and 0% of cases correspondingly. SBCs were present in 40.3%, SOECs in 16.7%, frontal bullar cells in 33.0% and FSCs in 10.8%. Because of its high prevalence and relative constant

position, ANCs are a reliable anatomic landmark to access the FR during surgical procedures. It also has become a reference cell for the majority of classification systems. Of note, the prevalence of frontal cell variants including anterior, posterior and midline group cells varies between various populations. Other frontal cell variants (other than ANCs) also vary between various populations [12, 13]. Regarding the size of the frontal sinuses, they grow at seventh or eighth year of age and undergo maturation after puberty [14, 15]. At 20 years, their sizes remain not changed until they undergo atrophy in advanced age [16]. The volume of FS varies greatly among subjects. In adult person, the mean size is approximately 10 cc and can reach a maximum of 37 cc [17].

In our study, aplasia was detected in 11 cases (2.2%), hypoplasia in 36 cases (7.2%) and hyperplasia in 105 (21%), while the large percent of the cases had medium sized sinuses (69.6%). This is in accordance with **Al Hatmi *et al.*** [18] who examined 610 cases (1220 CT scans) and demonstrated that the most prevalent category was medium-sized FS (13.3%), followed by hyperplasia (7.9%), hypoplasia (5.4%), and aplasia (2%). Likewise, in bilateral occurrence, the commonest category was medium-sized FS (53%), followed by hyperplasia (13.1%), hypoplasia (3.4%) and aplasia (2%).The medium-sized FS was the commonest category in other studies [19, 20].

On the other hand, another study reported that FS hyperplasia (44.5%) was the commonest category, followed by medium-sized FS (37.2%), FS hypoplasia (14.2%) and FS aplasia (4.1%) [21]. Also, **Buller *et al.*** [22] reported that FS hyperplasia was the commonest type (66%), followed by medium-sized FS (30.2%) and hypoplasia (3.8%). This significantly diverse prevalence can highlight that different populations have a substantial heterogeneity of individual frontal cell types [23]. The variable prevalence rates of SOECs might be due to its similar radiologic appearance to SBCs. The variability might also be due to differences in ethnicity. Also, frontal sinusitis can be responsible for a greater prevalence of posterior cells [24].

Based on Bent and Kuhn classification, frontal cells were categorized as type 1 (25.8%), type 2 (44.8%), type 3 (21%) and type 4 (8.4%). **Eweiss and Khalil** reported types I, II and III in 21.429, 26.429 and 22.143% correspondingly. Type IV was reported in only 8.571%. They recorded score 0, 1 and 2 on Lund-Mackay system (LMS) in 26.429%, 34.286% and 35.714% correspondingly. **Sharma** included a total of 100 cases and distributed them into two groups. Group A included 50 cases who had frontal sinusitis. Group B involved 50 control patients. They reported Kuhn types I, II, III and IV in 19% and 21%, 14% and 12%, 11% and 25%, 2% and 3% in groups A and B correspondingly. Type I showed the greatest ratio in group A and in total. Type III showed the greatest frequency in group B. Type IV was the rarest in groups A and B and also in total. Thy study recorded score zero, one and two on the LMS in 9.7% and 59.5%, 48.4% and 33.8%, 41.9% and 6.8% in groups A and B correspondingly**.**

Limitations: This study had some limitations. First, our sample size was small due to study time limits. This might have masked or increased the differences. Thus, it is recommended to conduct future studies on larger populations. Secondly, racial differences in the anatomy of FS are possible, making it difficult to conclude results to populations with various ethnicities.

CONCLUSION

Agger nasi cells were the most prevalent cells. The occurrence of IFAC cells was closely related to that found in our study. High-resolution CT scans can delineate the FRCs, which is important for preoperative assessment and treatment of pathologies related to the FS.

RECOMMENDATIONS

The following recommendations are suggested, utilization of CT as a routine procedure for any subjects who will undergo nasal sinuses surgeries, further multiple centers studies with larger number of cases should be conducted and evaluation of frontal recess cell in both normal and diseased sinuses.

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