The Relationship Between the Width of the Frontal Recess and the Frontal Recess Cells in Japanese Patients

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ABSTRACT

OBJECTIVE: The agger nasi cell (ANC) is an easily identifiable landmark when approaching the frontal sinus. The success of endoscopic frontal sinus surgery may be influenced by the width of the frontal recess (FR). The aim of this study is to examine the relationship between the FR width and the ANC size in Japanese patients. In addition, the effect of various frontal recess cells (FRCs) on the development of frontal sinusitis has been examined.

MATERIALS AND METHODS: Multiplanar computed tomography (CT) scans of the nasal cavities and paranasal sinuses in 95 patients (190 sides) before endoscopic sinus surgery were reviewed. The presence of FRCs, the thickness of the frontal beak (FB), the ANC size, and the anterior-to-posterior (A-P) length of the frontal isthmus (FI) and FR were evaluated in patients with and without frontal sinusitis.

RESULTS: The prevalence of the ANC, frontal cell types 1, 2, 3, and 4, frontal bullar cell (FBC), suprabullar cell, supraorbital ethmoid cell, and interfrontal sinus septal cell was 85.3%, 11.6%, 0%, 7.9%, 0%, 25.3%, 45.8%, 16.8%, and 15.3%, respectively. The ANC volume showed a significant positive correlation with the A-P length of the FI and FR. The incidence of frontal sinusitis in the patients with FBCs was significantly higher than that without FBCs.

CONCLUSION: A large ANC offers a greater potential to facilitating the approach to the frontal sinus because of the extensiveness of the FR in Japanese patients. The presence of FBCs may be related to a higher incidence of frontal sinusitis.

KEYWORDS: Frontal sinusitis, multiplanar computed tomography, frontal recess, anatomy, agger nasi cell

Introduction

The anatomical structures of the frontal recess (FR) and sinus are extremely complex. Because of the difficulty in detecting anatomical landmarks, the frontal sinus is the most likely area for endoscopic sinus surgery to fail. In addition, endoscopic frontal sinus surgery usually needs angled telescopes such as a 30°, 45°, or 70° endoscope and curved instruments. The lateral lamella of the cribriform plate on the inside of the FR, the lamina orbitalis on the outside of the FR, the anterior ethmoidal artery to the back of the FR, and the skull base in the posterosuperior region of the FR are dangerous structures in endoscopic frontal sinus surgery. Because they are adjacent to one another, there is a serious risk of surgical complications during the surgery. On the contrary, incomplete removal of cells within the recess has been reported to be the most common reason for continued frontal sinus symptoms after frontal sinus surgery.[1]

For the safety of each patient in surgery involving the FR, we need to understand the patient's anatomy through a pre-operative computed tomography (CT) scan. Wormald[2,3] proposed the Building Block Concept, in which building blocks are arranged 1 block for each cell to reconstruct each structure in the FR in 3 dimensions. By using the pre-operative CT scan, we can understand positional relationships in the FR and frontal sinus just like how blocks are put together and in turn can devise an appropriate drainage pathway from the frontal sinus to nasal cavity when creating the operative plan. By removing the frontal recess cells (FRCs) with curved instruments including forceps and a microdebrider in frontal endoscopic sinus surgery, we can make a wide drainage pathway, resulting in a successful surgery.

The FR width is an important factor to opening the frontal sinus. The uncinate process has been thought to be the key structure to understanding the FR.[4] An alternate approach is
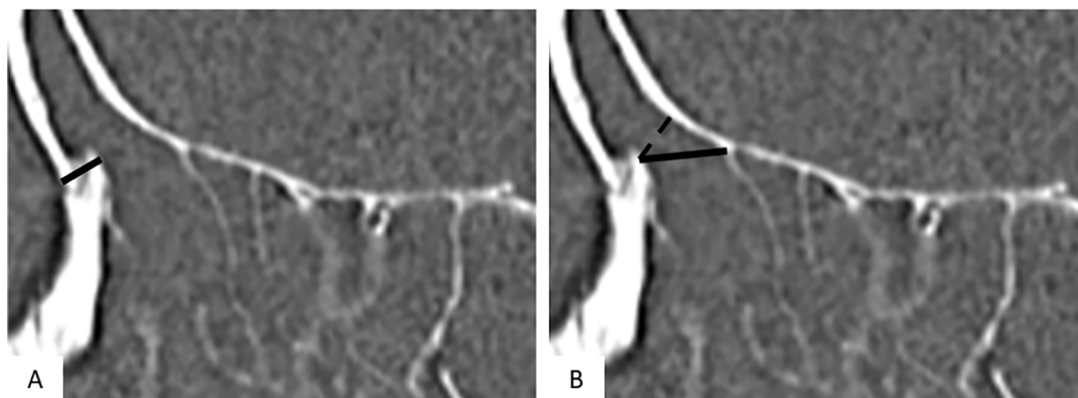
Figure 1. (A) The thickness of the frontal beak (FB, solid line) was measured in the parasagittal image where the FB was the most prominent. (B) The anterior-to-posterior (A-P) length of the frontal isthmus (FI, dotted line) was defined as the shortest length between the most prominent portion of the FB and the posterior table of the frontal sinus (FS). The A-P length of the frontal recess (FR, solid line) was defined as the length between the most prominent portion of the FB and the superior attachment of the ethmoidal bullar lamella.

to use the agger nasi cell (ANC) as an easily identifiable landmark.[2] The ANC size may be a significant factor to minimizing the degree of difficulty in the approach to the frontal sinus ostium. Not only how well the anatomy is understood but also the extensiveness of the FR may be related to the easiness of the approach.

In this study, we examined the relationship between the FR width and ANC size in Japanese patients. In addition, the effect of various FRCs on the development of frontal sinusitis was examined.

Materials and Methods

Patients

This study included 95 patients (54 men and 41 women) who underwent endoscopic sinus surgery for chronic rhinosinusitis (CRS) at Kagawa Rosai Hospital between April 2013 and March 2015. They had undergone a multiplanar CT scan of the nasal cavities and paranasal sinuses before the surgery. The exclusion criteria were as follows: previous sinus surgery, age < 18 years, maxillofacial fracture, and sinonasal tumor. The study was conducted in compliance with the 1975 Declaration of Helsinki, as revised in 2008, and was approved by the institutional review board of Kagawa Rosai Hospital.

Type of CRS

Chronic rhinosinusitis was defined by the diagnostic criteria outlined by the European Position Paper on Rhinosinusitis and Nasal Polyps 2012.[5] The CRS with nasal polyp (CRSwNP) patients were classified into eosinophilic chronic rhinosinusitis (ECRS) and non-eosinophilic chronic rhinosinusitis (non-ECRS) based on JESREC study criteria.[6] Eosinophilic chronic rhinosinusitis was defined histologically under the diagnostic criteria of an averaged eosinophil count of more than 70 per microscopic field (400× magnification) in 3 fields of the

subepithelial area of nasal polyps. The counts were conducted by 2 of the authors independently under light microscopy.

Radiological assessment of CRS

The CT scans (Toshiba Aquilion CT scanner; Toshiba Medical Systems, Tokyo, Japan) of the nasal cavities and paranasal sinuses were performed with contiguous axial cuts of 0.5 mm thickness. The CT data were then reconstructed into coronal and sagittal images on a computer workstation. The images from the CT scans were evaluated by 2 authors to minimize the variability of interpretation. The severity of CRS was assessed by CT scan using the Lund-Mackay radiological staging system.[7] Frontal sinusitis was considered to be present when the frontal sinus had mucosal thickening of greater than 3 mm on a CT scan involving the entire frontal sinus or its dependent portions of the sinus.[8]

Types of cells

The types of FRCs, including the ANC, frontal cell (FC), suprabullar cell (SBC), frontal bullar cell (FBC), supraorbital ethmoid cell (SOEC), and interfrontal sinus septal cell (IFSSC), were determined according to previously reported FRC criteria.[9] The thickness of the frontal beak (FB) and the anterior-to-posterior (A-P) length of the frontal isthmus (FI) and FR were measured on the same parasagittal plane where the FB was the most prominent. The A-P length of the FI was defined as the shortest length between the most prominent portion of the FB and the posterior table of the frontal sinus. The A-P length of the FR was defined as the length between the most prominent portion of the FB and the superior attachment of the ethmoidal bullar lamella (Figure 1). The ANC volume was measured using the parasagittal and coronal planes. The ANC volume was defined according to a previous study[10] using the longest A-P diameter in the parasagittal plane, the longest vertical diameter in the parasagittal plane,
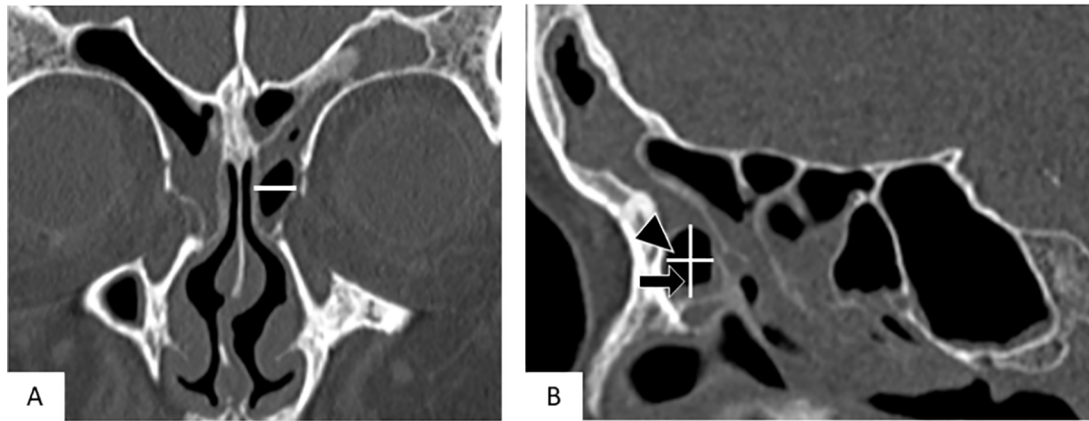
Figure 2. (A) The lateral diameter (solid line) of the agger nasi cell (ANC) was the longest diameter from side to side in the coronal image. (B) The longest anterior-to-posterior (A-P) diameter (arrowhead) and vertical diameter (arrow) of the ANC were measured in the parasagittal image.

Table 1. Demographic data for 95 patients, with 190 sides undergoing computed tomography.

	TOTAL	FRONTAL SINUSITIS		P VALUE
		POSITIVE	NEGATIVE	
Mean age (years)	53.7	54.1	53.2	>.05
Distinguishable sides	190	89	101	
Men:women ratio	108:82	63:26	45:56	<.001
Lund-Mackay score (±SD)	4.9 ± 3.5	6.5 ± 3.2	3.5 ± 3.2	<.001

P values: comparison between positive and negative in frontal sinusitis.

and the side with the longest lateral diameter in the coronal plane (Figure 2).

Statistical analysis

Continuous data are shown as median (interquartile range [IQR]) and categorical data are shown as percentages. The chi-square test was used to examine the differences with categorical variables. The differences of continuous variables between groups were analyzed with the Mann-Whitney *U* test. The Spearman's correlation coefficient by rank test was used to test the association between 2 variables. Values of $P < .05$ were considered statistically significant. All statistical analyses were conducted using the statistical software EZR (Easy R).[11]

Results

The 95 patients consisted of 53 patients with CRS without nasal polyp (CRSsNP) and 42 patients with CRSwNP. Of the patients with CRSwNP, 13 patients were ECRS and 29 patients were non-ECRS. A total of 190 sides from the 95 patients were assessed. The demographic data are summarized in Table 1. The total number of sides was 108 in men and 82 in women. The mean age of the patients was 53.7 years (range: 22-83 years). A diagnosis found that 89 sides had frontal sinusitis and 101 sides were without frontal sinusitis. There was no

significant difference in age between with frontal sinusitis and without frontal sinusitis. There was significant difference in men:women ratio between with frontal sinusitis and without frontal sinusitis (Table 1). We recruited consecutive cases who underwent endoscopic sinus surgery for CRS at Kagawa Rosai Hospital between April 2013 and March 2015. We did not arbitrarily exclude cases, and this study design was retrospective study. That is why we did not adjust for sex.

The prevalence of the ANC was 85.3% (162 sides). Frontal cells were identified in 19.5% (37 sides) of FRs; the prevalence was 11.6% (22 sides) for type 1, 0% (0 sides) for type 2, 7.9% (15 sides) for type 3, and 0% (0 sides) for type 4. Suprabullar cells, FBCs, SOECs, and IFSSCs were identified in 45.8% (87 sides), 25.3% (48 sides), 16.8% (32 sides), and 15.3% (29 sides), respectively (Table 2).

The FB thickness was 5.4 (IQR, 1.6) mm. The A-P lengths of the FI and FR were 8.0 (IQR, 3.2) and 11.0 (IQR, 4.4) mm, respectively. The A-P, superior-to-inferior, and lateral diameters of the ANC were 6.5 (IQR, 2.65), 8.7 (IQR, 3.8), and 6.1 (IQR, 2.2) mm, respectively. The average ANC volume was 352.8 (IQR, 316.2) mm³.

The ANC volume showed a positive correlation with the A-P length of the FI (bilateral: $r = .24, P < .01$; right sides only: $P < .05$; left sides only: $P < .05$) and the A-P length of the FR (bilateral: $r = .23, P < .01$; right sides only: $P < .05$; left sides

Table 2. Prevalence of frontal recess cells (FRCs) in various populations.

	LEE ET AL, CAUCASIAN	LIEN ET AL, TAIWANESE	CHO ET AL, KOREAN	HAN ET AL, CHINESE	LAI ET AL, TAIWANESE	KUBOTA ET AL, JAPANESE	OKUNI ET AL, JAPANESE	THIS STUDY JAPANESE
Anterior type (sides), n	82	363	114	404	174	300	156	190
ANC	86.3% (71)	89.0% (323)	94.0% (107)	94.1% (380)	90.8% (158)	88.0% (265)	90.7% (136)	85.3% (162)
FC type 1	35.4% (29)	21.5% (78)	22.8% (26)	24.4% (98)	35.6% (62)	37.0% (111)	28.8% (44)	11.6% (22)
FC type 2	20.7% (17)	10.5% (38)	14.0% (16)	7.0% (28)	10.9% (19)	6.3% (19)	0.6% (1)	0% (0)
FC type 3	8.5% (7)	7.7% (28)	7.9% (9)	8.2% (33)	6.9% (12)	4.3% (13)	2.6% (4)	7.9% (15)
FC type 4	0% (0)	0% (0)	0% (0)	0% (0)	1.1% (2)	1.3% (4)	0% (0)	0% (0)
Posterior type (sides), n	82	363	114	404	174	300	96	190
SBC	11% (9)	39.1% (142)	39.5% (45)	36.3% (148)	52.9% (92)	37.0% (111)	81.3% (78)	45.8% (87)
FBC	6.1% (5)	6.3% (23)	14.0% (16)	9.0% (36)	14.9% (26)	7.0% (21)	25.0% (24)	25.3% (48)
SOEC	64.6% (53)	7.7% (28)	2.6% (3)	5.4% (22)	3.4% (6)	6.0% (18)	Unenrolled	16.8% (32)
Medial type (sides), n	82	363	114	404	174	300	161	190
IFSSC	7.3% (6)	9.6% (35)	8.8% (10)	12.4% (25)	9.2% (16)	8.6% (26)	12.4% (20)	15.3% (29)

Abbreviations: ANC, agger nasi cell; FBC, frontal bullar cell; FC, frontal cell; IFSSC, interfrontal sinus septal cell; SBC, suprabullar cell; SOEC, supraorbital ethmoid cell.
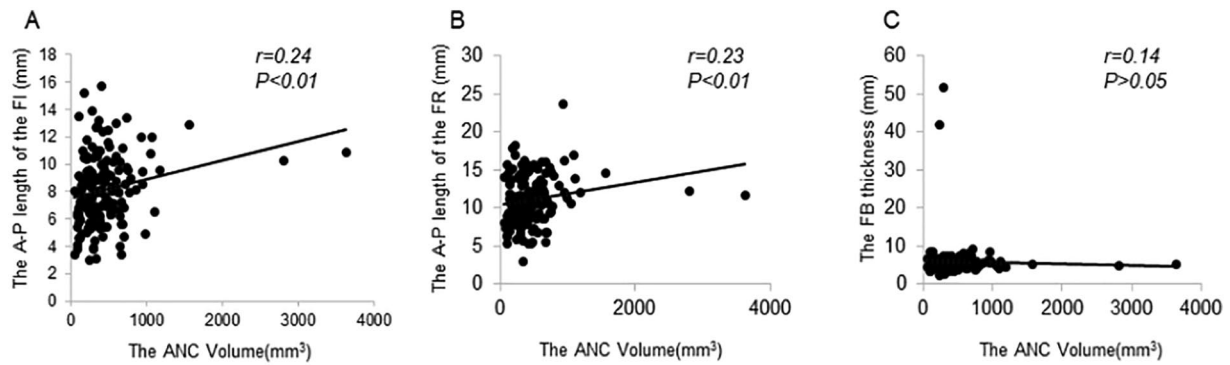
Figure 3. The ANC volume showed a positive correlation with the A-P length of the FI (A: $r=.24$, $P<.01$) and the A-P length of the FR (B: $r=.23$, $P<.01$). However, there was no statistically significant correlation between the ANC volume and the FB thickness (C: $r=.14$, $P>.05$). ANC indicates agger nasi cell; FI, frontal isthmus; A-P, anterior-to-posterior; FR, frontal recess; FB, frontal beak.

only: $P>.05$). However, there was no statistically significant correlation between the ANC volume and the FB thickness ($r=.14$, $P>.05$; Figure 3).

The positive and negative results of each FRC in the patients with and without frontal sinusitis are shown in Table 3. The patients with FBCs had a significantly higher incidence of frontal sinusitis than the patients without FBCs (bilateral: $P<.05$; right sides only: $P<.05$; left sides only: $P>.05$). There was no significant difference in the incidence of frontal sinusitis between the patients who were positive and negative for the ANC, FC type 1, FC type 3, SBC, SOEC, and IFSSC (Table 3). There was no correlation between the incidence of frontal sinusitis and the size of ANC.

There was no significant difference in the A-P length of the FI between the patients with frontal sinusitis, 8.1 (IQR, 3.8) mm, and the patients without frontal sinusitis, 8.0 (IQR, 3.4) mm. There was also no significant difference in the A-P length of the FR between the patients with frontal sinusitis, 10.6 (IQR, 3.8) mm, and the patients without frontal sinusitis, 11.0 (IQR, 5.0) mm. No statistically significant difference was observed in the A-P length of the FI and FR between the patients with FBCs, FI: 8.7 (IQR, 3.6) mm, FR: 11.0 (IQR, 4.7) mm, and the patients without FBCs, FI: 7.8 (IQR, 3.7) mm, FR: 10.8 (IQR, 3.8) mm.

Discussion

Due to the intrinsic complexity of the anatomy of the FR, surgeons sometimes hesitate when approaching the frontal sinus ostium. Many types of FRCs such as the ANC, FC types 1-4, SOEC, SBC, FBC, and IFSSC fill this narrow space. Preoperative evaluation on variations of FRCs is necessary for complete removal of these cells, which will ensure frontal patency and restoration of the mucociliary clearance of the frontal sinus.

To understand the anatomy of the FR, multiplanar CT is essential.[12,13] For this study, multiplanar CT analysis was chosen, and 0.5-mm slice coronal and sagittal views were reformatted from a 0.5-mm axial slice CT. Simultaneous evaluation

Table 3. Positive and negative results for each frontal recess cell in patients with and without frontal sinusitis.

	FRONTAL SINUSITIS		*P* VALUE
	POSITIVE (N = 89)	NEGATIVE (N = 101)	
FBC (n)			
Positive	29	19	.029
Negative	60	82	
ANC (n)			
Positive	76	86	.962
Negative	13	15	
FC type 1 (n)			
Positive	14	8	.093
Negative	75	93	
FC type 3 (n)			
Positive	10	5	.109
Negative	79	96	
SBC (n)			
Positive	40	47	.826
Negative	49	54	
SOEC (n)			
Positive	10	22	.053
Negative	79	79	
IFSSC (n)			
Positive	14	15	.867
Negative	75	86	

Abbreviations: ANC, agger nasi cell; FBC, frontal bullar cell; FC, frontal cell; IFSSC, interfrontal sinus septal cell; SBC, suprabullar cell; SOEC, supraorbital ethmoid cell.

of coronal, axial, and sagittal views is essential to preventing misunderstanding of the FR anatomy.

A comparison of the percentages of various FRCs identified in CT images among Japanese, Taiwanese, Chinese, Korean, and Caucasian adult populations is shown in Table 2.[8,9,12-16] Several studies have reported that approximately 90% of cases of East Asians and Caucasians have the ANC. Our results demonstrated that the prevalence of the ANC was 85.3%, similar to previous findings.

This study showed a positive correlation between the ANC size and the A-P length of the FI and FR. Previous reports also found a positive correlation between the FR distance and the ANC size.[10,17] A large ANC offers a greater potential to facilitating the approach to the frontal sinus because of the extensiveness of the FR. In this study, we found no correlation between the ANC size and the FB thickness. Wormald[2] previously reported that a large ANC and frontal ethmoidal cell pneumatization reduced the size of the beak, whereas the absence of this cell would produce a thick beak. On the contrary, Park et al[10] reported that there was no correlation between the ANC size and the FB thickness. They also indicated that a large ANC will push the posterior table of the frontal sinus and superior attachment of the anterior wall of the ethmoid bulla posteriorly, increasing the A-P length of the FI and/or FR regardless of the FB thickness.[10] Our results support the opinion of Park et al for there was also no correlation between the ANC size and the FB thickness in this study.

The pathophysiology of the frontal sinusitis is associated with ventilation of the sinus via the sinus ostium. The size of the frontal sinus ostium is key to frontal sinus drainage.[15] There is a possibility that the presence of FRCs and inflammation of FRCs cause narrowing of the drainage pathway from the frontal sinus, and that is why frontal sinusitis may happen. We also checked whether FRCs were associated with frontal sinusitis in Japanese patients. In this study, only the presence of FBCs had an effect on the development of frontal sinusitis, whereas the other FRCs (anterior types such as the ANC, FC type 1, and FC type 3, medial types such as the IFSSC, and posterior types such as the SBC and SOEC) had no relevance to the development of frontal sinusitis. Similarly, although we showed a positive correlation between the ANC size and the A-P length of the FI and FR, the ANC had nothing to do with the development of frontal sinusitis. The previous report showed a lack of statistically significant differences in the frequency of frontal sinusitis based on the size of the FI.[1] The presence of FC type 3 and FC type 4 was reported to be associated with a higher incidence of frontal sinusitis.[18] On the contrary, it was reported that the presence of FCs did not correlate with a greater incidence of frontal sinusitis in the data from DelGaudio et al.[1] The prevalence of FC type 3 was a little higher than reported in other Japanese patient groups, but FC type 3 had no effect on the development of frontal sinusitis in this study.

Frontal bullar cells are characterized by the ethmoid cell above ethmoid bulla, pneumatizing along the skull base into the frontal sinus from the posterior FR and located behind the true frontal sinus pneumatization tract.[10] In addition, a CT analysis of 300 sides showed that the prevalence of the FBC was associated with the development of frontal sinusitis in Japanese patients.[15] In Taiwanese patients, the presence of FBCs was related to a higher incidence of frontal sinusitis, presumably due to narrowing of the frontal sinus drainage pathway mainly through significant shortening of the A-P length of the frontal ostium and FR.[8] In this study, FBCs did not shorten the A-P length of the FR. Frontal bullar cells blocked the drainage pathway from the posterior FR, which is why frontal sinusitis tended to happen irrespective of the existence of FBCs.

It was reported that frontal sinus obstruction is due to narrowing of the frontal sinus drainage pathway by any of its bony surroundings, mucosal edema, polyps, scarring, and adhesions caused by trauma, infection, or previous surgery.[19] A previous report showed that multiple findings can be identified as contributing to FR obstruction requiring revision sinus surgery.[20] Seven findings were identified: mucosal disease (67%), retained ethmoid cells (53%), lateralized middle turbinates (30%), retained ANCs (13%), scar (12%), retained FCs (8%), and neo-osteogenesis (7%).[19] In the primary surgery, we assumed that surgeons try to completely remove FRCs to prevent the revision surgery for frontal sinusitis. There are a lot of factors including polyps and mucosal inflammation in addition to complicated FRCs that lead to refractory frontal sinusitis. We need to further investigate the relationship between the FR variations and the development of frontal sinusitis in a large-scale group study.

Conclusions

A large ANC offers a greater potential to facilitating the approach to the frontal sinus because of the extensiveness of the FR in Japanese patients. The ANC is thought to be very important as not only an easily identifiable landmark but also an indicator of ease of endoscopic frontal sinus surgery. The presence of FBCs can be related to a higher incidence of frontal sinusitis.

Author Contributions

SM and SK contributed to the design, implementation and presentation of the research, the writing of the manuscript and editing of the manuscript. SM, SK, MO, TN, KU, JM, YN, and KN contributed to the analysis of the results and the scientific discussion on the topic.

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