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ANALYSIS OF ANATOMICAL VARIANTS OF FRONTAL SINUS OUTFLOW TRACT (FSOT) BY MULTIPLANAR RECONSTRUCTION MDCT SCAN IMAGES

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ABSTRACT

Background: The width of frontal sinus outflow tract is determined by pneumatisation pattern of frontal recess cell. The purpose of this study is to determine correlation between volume of agger Nasi cell (ANC) with frontal beak thickness, A-P length of frontal isthmus (FI) and frontal recess (FR).

Materials and Methods: A cross sectional study was conducted in 140 adult patients who had computed tomography (CT) brain done in HUSM from Jan 2010 to June 2018. Multiplanar reconstructed images then retrieved from PACS system. Prevalence and pattern of pneumatisation of frontal recess cell reviewed. Agger Nasi cell volume measured with analysis of its correlation to frontal beak thickness, length of frontal recess and frontal isthmus done by researcher using Pearson correlation test.

Result: ANC found in 131 out of 140 adult patients (93.6%). Mean ANC volume 434.48 with standard deviation of 256.63. For frontal beak (FB) thickness, anterior-posterior (A-P) length of FI & FR, mean values were 6.24 (SD 1.61), 7.06 (SD 2.92) and 4.95 (SD 2.97) respectively. No significant correlation was found between volume of ANC with FB thickness, A-P length of FI and FR.

Conclusion: There was no statistically significant correlation between volume of ANC with the frontal beak thickness, anterior posterior length of frontal isthmus and frontal recess ($p>0.05$). Since ANC is commonly found in population, it is still essential for radiologist to consider reporting the ANC volume and pattern of pneumatisation when endoscopic surgery is planned.

Keywords: Agger nasi cell, frontal recess cell, multiplanar reconstruction, correlation.

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1.0 Introduction

Frontal sinus outflow tract (FSOT) or synonymously known as frontal recess (FR) is the space through which the frontal sinus drains (Huang, Lloyd, DelGaudio, Jablonowski, & Hudgins, 2009). It is a complex space with the shape resembles an inverted funnel hourglass appearance which its 'waist' demarcates the level of frontal sinus floor (Daniels *et al*., 2003). Its shape is inconsistent with the variable anatomy and pneumatisation pattern of FR cell. The latest classification currently used is modified Kuhn classification (Lee, Kuhn, & Citardi, 2004) which allows accurate characterization and configuration to be understood by surgeons. The tract is bounded anteriorly by the agger nasi, laterally by the orbit and medially by the middle turbinate. Posteriorly the tract depends on skull base structure which is ethmoid bulla or bulla lamella (Smith, Loehrl, & Smith, 2001). The first cell in the classification is agger nasi cell (ANC) which is present in almost 90% of the population in most of the studies (Ahmet Altıntaş *et al*., 2017; Makihara *et al*., 2019; Park, Yoon, Cho, & Roh, 2010). It is defined as pneumatisation of the agger nasi region and the most anteriorly located ethmoid air cell. The second most common is frontoethmoidal cell which is the anterior ethmoidal cell that is associated with frontal process of maxilla and sit on top of ANC with 4 subtypes; 1, 2, 3 & 4 (Peter, 2003). Some literatures give different nomenclature such as frontal cell (Lee et al., 2004), and supra agger cell (Tran, Ngo, & Psaltis, 2019). Suprabullar cell can be found above the ethmoidal bulla in the posterior FR. Once it is seen extending and pneumatising along the skull base into the frontal sinus superiorly, it is called frontal bulla cell. Supraorbital ethmoidal cell is defined as pneumatisation of orbital plate of frontal bone. It may mimic the appearance of septate frontal sinus. Interfrontal sinus septal cell (ISSC) is characterized by pneumatisation into the interfrontal sinus septum (Lee *et al*., 2004).

Acute rhinosinusitis is defined as a mucosal inflammatory disease of the paranasal sinuses and nasal cavity (Husain, Amilia, Rosli, Zahedi, & Sachlin, 2018). Rhinosinusitis is a common medical problem in the United States, affecting 14% - 16% of its adult population (Huang *et al*., 2009), while in Asian population it is estimated from 2 - 8% (We *et al*., 2015; Zhang *et al*., 2017). The current treatment for sinusitis is always to be medical therapy, and most of the patients respond adequately to a combination of antibiotics, decongestants, mucolytics and steroids. However, in a significant proportion of patients with sinusitis, medical management alone is insufficient to relieve symptoms necessitating referrals to rhinologists for consideration of surgical treatment (Maccabee & Hwang, 2001)

Functional endoscopic sinus surgery main purpose is to remove any anatomical obstructions and improve the mucociliary clearance along the sino-nasal physiological pathways that prevent proper mucosal drainage (Grech *et al*., 2013). Modern progression of endoscopic exploration of lateral nasal wall has been improved through the development of various instruments for use in endoscopic sinus surgery which aims to restore the normal function of the sinuses (Tajudeen & Kennedy, 2017; Head and Neck, East Kent Hospitals, 2019). Currently, endoscopic sinus surgery is a common operation which is proven to be very useful for treating frontal sinus disease and has been accepted as the treatment of choice for frontal sinus condition (Takasaki, Umeki, Enatsu, Kumagami, & Takahashi, 2010) with reported success rates as high as 98% (Huang *et al*., 2009) for primary intervention and 78% for revision cases (Maccabee & Hwang, 2001). However, inadequate removal of cells obstructing the outflow of the frontal sinus can cause disease recurrence (Makihara *et al*., 2019). In the latest approach, ANC is used as the

main landmark to understand the anatomy of frontal recess instead of using the uncinate process as in the past (Peter, 2003).

The anterior location and tight confinement between the orbit and anterior skull base make the FR a notoriously difficult area to treat with endoscopy. It has been reported to be an area that showed significant predilection for stenosis after endoscopic intervention (Kuhn & Javer, 2001). The close proximity of FR to the anterior ethmoid artery, orbit and anterior cranial fossa may result in serious complications like post-operative scarring, stenosis and disease recurrence. Adequate exposure is necessary to produce effective frontal sinus surgery (Daniels *et al*., 2003). In case of more advanced disease, it may require surgical enlargement of FSOT. The FR is enlarged surgically in the anterior posterior dimension through the clearance of ANC (Pletcher, Sindwani, & Metson, 2006).

The FSOT is bounded anteriorly by ANC and frontal beak (FB). Since it is commonly found in the population, understanding of its anatomy greatly facilitates the surgical approaches to the frontal sinus. Peter stated that large ANC reduces the thickness of FB (Peter, 2003) while Park and Makihara found no correlation at all between the volume of ANC and FB thickness (Makihara *et al*., 2019; Park *et al*., 2010). This complex bony anatomical configuration need computed tomography (CT) which is widely utilized as an essential imaging tool in the diagnosis and evaluation of bony pathology in patients. The principle behind it is the use of x-rays to build cross-sectional images (slices) of the body. The image is later reconstructed from the raw data of the images acquired from traditional axial plane using complex mathematical algorithms to produce 3-dimensional images by multiplanar reconstruction (MPR) (Rydberg *et al*., 2000). Radiographic delineation of this paranasal sinuses region provides preoperative information regarding morphology and pathology which lead to more focused endoscopic surgery. The FR or outflow tract can be entered in a predetermined sequential manner and then, explored to reduce the morbidity.

The interaction between otolaryngologist and radiologist need to be effective as the latter must be familiarized with these microanatomic locales and able to differentiate between normal and disturbed anatomy (Kennedy & Rosenbaum, 1987). This will allow otolaryngologist to be able to turn to the CT scan at any point during the dissection and identify the cell that is currently being dissected. A standardized CT report has been suggested to reduce the error or knowledge gap among radiologist when interpreting the paranasal region CT images. Correlation with clinical findings and proper indication of study are needed from the primary team to determine the critical and non-critical structures which may or may not be related to the technique of the surgery and to reduce major adverse event during surgery. There are insufficient numbers of the study that primarily focus to the effect of the ANC volume to FB, FI and FR. Thus, this study aimed to establish a cut-off point with high sensitivity and specificity in order to provide database in Universiti Sains Malaysia Hospital for pre-operative planning.

2.0 Materials and Methods

This was a cross sectional study which was conducted in Universiti Sains Malaysia Hospital, in Kelantan, a northeastern region of peninsular Malaysia (Arif, Awang & Abdullah, 2019). Data was retrieved from January 2010 until June 2018 by querying the CT examination performed using keyword “CT Brain”. Inclusion criteria were all patients aged 18 years and

above, and paranasal sinuses region included in the field of view. The exclusion criteria were patient with facial trauma or infection involving paranasal sinuses and previous history of paranasal sinus surgery. Prevalence of frontal recess variants and pneumatisation pattern were reviewed. ANC volumes were determined and its correlation with FB thickness, length of FI and FR were analysed.

Sample size was calculated using single proportion formula. Using proportion of 0.1% of agger nasi cell and frontal recess cell from previous study (Park *et al*., 2010), precision of 5% and level of confidence of 95%, the total sample size required was 139 samples. Subject's information were collected which included age, prevalence of each FR cell types (presence/absence), volume of ANC in mm^3, FB thickness in millimetre, A-P length of FI and FR in millimetre (mm) and were measured (Figure 1-4). Images were viewed using CT number windowing of WW 2500 and WC 480 and recorded in the data collection sheet. All values were measured at least three times and mean values were documented.

We used SPSS Statistics (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp) for data entry and analysis. Prevalence of FR cell variant was based on widely accepted classification; modified Kuhn classification (Lee et al., 2004). For correlation study of volume of ANC with FB thickness, A-P length of FI and FR, Pearson's correlation test was used. A p-value of less than 0.05 was considered statistically significant. The study was approved by Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/18020123), which complies with the Declaration of Helsinki.

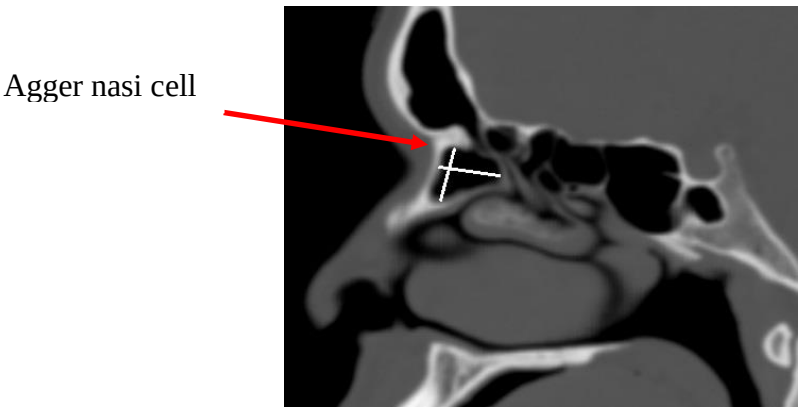

Figure 1: Measurement of ANC volume in parasagittal – longest diameter from anterior to posterior and superior to inferior.

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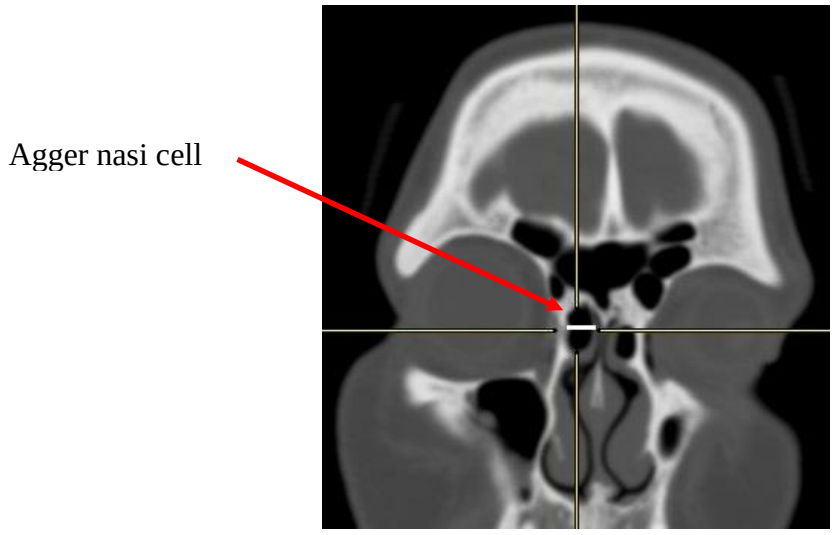

Figure 2: Measurement of ANC volume in coronal – longest diameter from side to side.

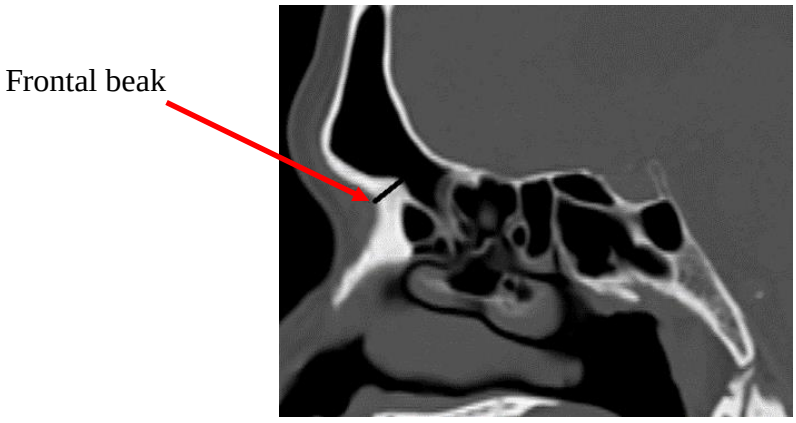

Figure 3: Thickness of FB in parasagittal – measured where the FB point most prominent.

Ethmoid bulla lamella superior border

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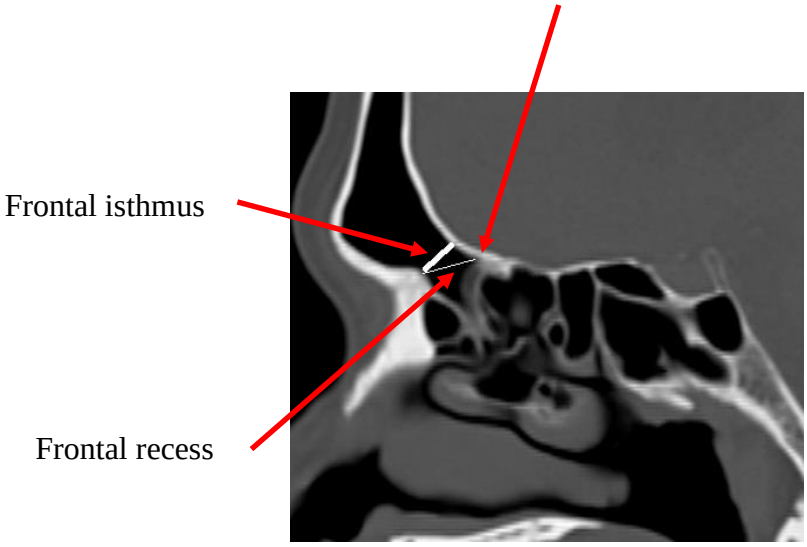

Figure 4: A-P length of FI (solid thick white line) – the shortest length between FB and posterior wall of frontal sinus. A-P length of FR (solid thin white line) – the length between the most prominent of FB and superior border of ethmoid bulla lamella to the skull base.

3.0 Result

A total of 140 adult patients recruited for this study. The result of the data showed the proportion of frontal recess cell variant in the population based on modified Kuhn classification. The ANC was observed in 131 sides (93.6%). The prevalence of frontoethmoidal cells were noted in 79 sides (56.4%); type 1 is 37.9%, type 2 is 12.1%, type 3 is 6.4%. Type 4 was not identified. The prevalence of FBC, supraorbital ethmoid cells, suprabullar cell and ISSC were 26.4%, 25.7%, 0.7% and 9.2% respectively (Table 1).

The anatomic measurements of FSOT are showed in Table 2. The mean (±SD) measurement of ANC shows anterior-posterior, superior-inferior and lateral diameters of ANC were 7.48 (±2.20) mm, 9.18 (±3.07) mm and 5.85 (±1.47) mm respectively. The mean (±SD) volume of ANC calculated as 434.48 (±256.63) mm^3. The mean and standard deviation (±SD) thickness of FB was 6.24 (±1.61) mm. The mean and (±SD) of anterior-posterior length of FI and FR were 7.06 (±2.92) mm and 495 (±2.97) mm respectively.

Table 1: Prevalance of agger nasi cell and frontal recess cell (n=140)

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Cell types	Prevalence (%)
Aggar nasi cell	131 (93.6)
Frontoethmoid (type)	
I	53 (37.9)
II	17 (12.1)
III	9 (6.4)
IV	0 (0.0)
Frontal bullar cell	37 (26.4)
Supraorbital ethmoid	36 (25.7)
Suprabullar cell	1 (0.7)
Interfrontal sinus septal cell	13 (9.2)

Table 2: Measurement of ANC, FB, FI, FR (n=140)

Variables	Mean (±SD)
Agger nasi cell	
Lateral (Coronal View)	5.85 (±1.47) mm
Anterior-Posterior (Sagittal View)	7.48 (±2.20) mm
Superior-Inferior (Sagittal View)	9.18 (±3.07) mm
Volume (mm^3)	434.48 (±256.63) mm^3
Frontal Beak (mm)	6.24 (±1.61) mm
Frontal Isthmus (mm)	7.06 (±2.92) mm
Frontal Recess (mm)	4.95 (±2.97) mm

Based on these data, using Pearson correlation analysis, the volume of ANC showed no significant correlation with thickness of FB (r=0.17; *p*>0.05). The volume of ANC also showed no significant correlation with the A-P length of FI (r=0.02; *p*>0.80) and A-P length of FR (r=0.06; *p*>0.49) as shown in Table 3.

Table 3: Correlation between volume of ANC with A-P length of FI and FR (n=140).

Variables r (*p*-value)	**Frontal beak**	**Frontal isthmus**	**Frontal recess**
ANC volume	0.17 (0.051)	0.02 (0.801)	0.06 (0.494)

r= Pearson correlation coefficient

4.0 Discussion

Complete understanding of FSOT is crucial for a successful surgery. Complications such as recurrence and stenosis can be avoided by complete removal of the FR cell to restore its mucociliary clearance. High resolution CT with MPR and simultaneous evaluation of coronal, axial and sagittal views is the key for better understanding of the FR anatomy. This study purpose is to analyse the pneumatisation pattern of the FR and how the surrounding structures affect its anatomy and the drainage pathway. The modified Kuhn classification (Lee *et al*., 2004) which is widely accepted nowadays, include the ANC, frontoethmoid type1-4, supraorbital ethmoid, frontal bulla, supra bullar and ISSC. ANC is reported as the most commonly found which was 80% to 95% in various studies (Park *et al*., 2010; Ahmet Altıntaş *et al*., 2017; Makihara *et al*., 2019; Tran *et al*., 2019). Our results demonstrated that prevalence of the ANC was 93.6% which is almost similar to other studies.

Previously the sinus outflow tract was determined by the uncinate process insertion which is lamina papyracea, middle turbinate or skull base. The use of ANC as new landmark for the frontal recess has been proposed by several studies (Kubota, Takeno, & Hirakawa, 2015; Peter, 2003). It is reported that the course, width and depth of the FSOT is determined by the ANC size of volume which lies antero-laterally and inferiorly to the frontal recess (Park *et al*., 2010).

Our initial hypothesis was that large pneumatisation (volume) of ANC reduces the thickness of FB which was found in previous study (Wormald, 2005). In this study, we discovered that there was no correlation between volume of ANC with the FB thickness. This result is similar with a few other studies (Park *et al*., 2010; Makihara *et al*., 2019; Ahmet Altıntaş *et al*., 2017). There was also no significant correlation between ANC volume with A-P length of FI and/or FR. Our initial expectation was that large ANC may pushes the posterior table of frontal sinus resulting in increasing the A-P length of FI/FR regardless of the thickness of FB. Three studies found weak to moderate positive correlation between volume of ANC with A-P length of the FI/FR (Park *et al*., 2010; Makihara *et al*., 2019; Tran *et al*., 2019). On the contrary, Ahmet *et al*. (2017) found no correlation at all in all of the correlation analysis (p>0.906).

Our result is similar with Ahmet *et al.* (2017) but greatly different with Park *et al*. (2010) and Makihara *et al*. (2019). The limitation may include non-probability sampling as all available samples were conveniently recruited. This limitation may be prevented if the large sample size can be taken so that our study could be more informative. Another pitfall could be due to imaging parameters and poor definition of specific anatomical landmark in determining the correct point during our measurement which may not accurately show the actual course, width and depth of frontal recess as small of millimetre differences may result significant changes in value. Measurement accuracy may also be biased due to quality control technique, the radiological technologist skills, and patient positioning or artefact which all lead to reduce efficacy of measurement precision.

5.0 Conclusion and recommendation

As a conclusion, our results suggested that no correlation was found between volume of ANC with FB thickness, A-P length of FI and FR. Since ANC is commonly found in population, it is still essential for radiologist to consider reporting the ANC volume and pattern of pneumatisation when endoscopic surgery is planned. We suggest further studies to be carried out in the future with larger participants or samples to explore the relationship between the ANC and other FRC variant.

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Declaration

The authors declare that this manuscript has never been published in any other journal.

Authors contribution

Author 1: Conceptualization, data entry, data analysis, manuscript drafting.
Author 2: Data analysis and manuscript review.
Author 3: Conceptualization, manuscript drafting and review.
Author 4: Conceptualization, manuscript drafting and review.

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