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

DR AHMAD FIRDAUS BIN MOHAMED

Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Medicine (Radiology)

UNIVERSITI SAINS MALAYSIA

2020

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

by

DR AHMAD FIRDAUS BIN MOHAMED

Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Medicine (Radiology)

UNIVERSITI SAINS MALAYSIA

MAY 2020

ACKNOWLEDGEMENTS

I would like to express my gratitude to Allah SWT for giving me the opportunity and endlessly guiding me in completing the thesis. The completion of this thesis could also not have been possible without the participation, cooperation and assistance from so many people whose names may not all be enumerated. Their contributions are sincerely appreciated and gratefully acknowledged. However, I would like to express deep and utmost appreciation particularly to the following:

1. Prof Madya Dr Mohd Ezane Aziz as my supervisor, who had provided assistance and guidance in carrying out this study until its completion.
2. I would also like to express deep appreciation to Prof. Dr. Baharudin Abdullah as co-supervisor for this dissertation and also for his guidance and supervision.
3. Prof Madya Dr Mohd Shafie Abdullah, Dr Khairil Amir Sayuti, Dr Juhara Haron, Dr Ahmad Tarmizi Musa, Dr Chandran Nadarajan, Dr Wan Aireene Wan Ahmed, Dr Ahmad Hadif Zaidin Samsudin and Dr Nur Asma Sapiai lecturers/radiologists all of whom directly or indirectly contributed their ideas and comments to the success of this study.
4. Colleagues and all the staffs in the Department of Radiology, HUSM.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ..... **i**

TABLE OF CONTENTS ..... **ii**

LIST OF TABLES ..... **v**

LIST OF FIGURES ..... **vi**

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMNS ..... **vii**

ABSTRAK ..... **viii**

ABSTRACT ..... **x**

CHAPTER 1 INTRODUCTION **2**

1.1 Background 2

1.2 Research Question 4

1.3 Objectives 5

1.3.1 General objective 5

1.3.2 Specific objectives 5

CHAPTER 2 LITERATURE REVIEW **7**

2.1 Anatomy of the Frontal Sinus Outflow Tract and its variants 7

2.2 Pneumatisation variants of frontal recess cells 8

2.2.1 Modified Kuhn classification of frontal recess cells 8

2.2.2 3 Dimension Concept of Analysis of Frontal Recess & Sinus Anatomy 15

2.3 Paranasal Sinus – Goal of Current Treatment 17

2.3.1 Paranasal Sinuses Disease - Medical Treatment & Endoscopic diagnosis 17

2.3.2 Surgery of Frontal Recess and Frontal Sinus 18

2.3.3 Priciples of Functional Endoscopic Sinus Surgery (FESS) 19

2.4 Agger nasi cell (ANC) – The key that unlocks the frontal recess 20

2.5 Role of Radiologist in Reporting the Paranasal Sinus Computed Tomography 21

2.6 Rationale of Study 23

CHAPTER 3 METHODOLOGY 25

3.1 Study Design 25

3.2 Study Population 25

3.3 Sample Size Calculation 25

3.4 Sampling Method 27

3.5 Inclusion Criteria 27

3.6 Exclusion Criteria 27

3.7 Materials 28

3.8 Methods 29

3.8.1 Image acquisition 29

3.8.2 Image analysis and interpretation 29

3.8.3 Data collection 35

3.9 Confidentiality and Privacy 35

3.10 Hypothesis & Statistical Analysis 35

3.11 Ethical consideration 36

CHAPTER 4 MANUSCRIPT 38

CHAPTER 5 60

5.1 Conclusion 61

5.2 Future Recommendations 61

APPENDIX A: Size calculation for pneumatisation variants of FR 62

APPENDIX B: Sample size calculation 63

APPENDIX C: Data collection sheet 64

APPENDIX C: Data collection sheet 65

APPENDIX D: Human Ethical Approval 66

APPENDIX E: Instructions to Authors of Selected Journal 68

CHAPTER 6 LIST OF PUBLICATIONS 70

LIST OF TABLES

Table 1 : Standard CT Scanners and Tools/Protocol 29

LIST OF FIGURES

Figure 1 : Frontal recess cells : agger nasi and suprabullar cell. 9

Figure 2 : Frontal recess cell :Type 1 frontoethmoid cell..... 10

Figure 3 : Frontal recess cell : Type 2 frontoethmoidal cell..... 11

Figure 4 : Frontal recess cell : Type 3 frontoethmoidal cell..... 12

Figure 5 : Frontal recess cell : Frontal bullar cell..... 13

Figure 6 : Frontal recess cell : Interfrontal sinus septal cell (IFSS) 14

Figure 7 : Building block concept of frontal recess and sinus anatomy..... 16

Figure 8 : Measurement of ANC volume in parasagittal view. 31

Figure 9: Measurement of ANC volume in coronal view..... 32

Figure 10: Thickness of FB in parasagittal view. 33

Figure 11: A-P length of FI..... 34

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMNS

MDCT	Multi Detector Computed Tomography
MPR	Multiplanar Reconstruction
FSOT	Frontal Sinus Outflow Tract
FESS	Functional Endoscopic Sinus Surgery
ANC	Agger Nasi cell
FB	Frontal Beak
FI	Frontal Isthmus
FR	Frontal Recess
PNS	Paranasal Sinus
A-P	Anterior-Posterior
FS	Frontal Sinus
mm	millimetre
PACS	Picture Archiving and Communication System
HUSM	Hospital Universiti Sains Malaysia
POP	Punch Out Procedure
ISSC	Intersinus Septal Cell

ANALISIS VARIASI ANATOMI ALIRAN KELUAR TREK FRONTAL SINUS MENGGUNAKAN IMBASAN CT DAN KOSTRUKSI TIGA DIMENSI PELBAGAI SATAH

ABSTRAK

Pengenalan: Frontal sinus adalah struktur kompleks dan mempunyai variasi laluan aliran trek berbanding paranasal sinus yang lain. Ia penting untuk navigasi endoskopi yang selamat semasa pembedahan. Ia termasuk frontal infundibulum, ostium dan reses yang membentuk laluan pengeluaran rembesan. Laluan sebenar mungkin berbeza bergantung kepada bentuk pneumatasi tulang di sekeliling trek. Sel agger nasi adalah sel yang paling biasa di temui dalam populasi dan ia memainkan peranan sebagai penanda penting anatomi untuk reses. Isipadu sel agger nasi bergantung kepada ketebalan paruh frontal, panjang frontal ismus dan frontal reses. Tujuan kajian ini dijalankan adalah untuk menentukan kaitan antara isipadu sel agger nasi dengan ketebalan paruh frontal, panjang frontal ismus dan frontal reses di kalangan pesakit dewasa di Hospital Universiti Sains Malaysia (HUSM)berdasarkan fakta bahawa terdapat kaitan yang penting antara isipadu Agger Nasi sel terhadap ketebalan paruh frontal, panjang frontal ismus dan frontal reses.

Metodologi: Kajian keratan rentas telah dijalankan ke atas 140 pesakit dewasa yang menjalani imbasan CT Otak dan tidak mempunyai sejarah pembedahan di kawasan frontal sinus di HUSM dari Januari 2010 hingga Jun 2018. Imej 3 dimensi direkonstruksikan dengan kaedah pelbagai satah daripada data CT otak berketebalan 1mm. Imej koronal (pandangan depan) dan parasaggital (pandangan sisi) menghasilkan

imej yang jelas menunjukkan sel frontal sinus, bentuk pneumatasi, lokasi dan variasi sel. Ukuran isipadu sel agger nasi, ketebalan paruh frontal, panjang frontal ismus dan frontal reses dijalankan melalui algoritma kernel yang jitu dan bernilai tinggi dan seterusnya dianalisis menggunakan formula ‘Pearson correlation test’ untuk mengetahui perkaitan masing-masing.

Keputusan: Daripada 140 pesakit dewasa, 131 ANC ditemui. Purata isipadu ANC adalah 434.48mm^3 dengan sisihan piawai (SP) 256.63. Untuk ketebalan paruh frontal, panjang A-P untuk frontal ismus dan frontal reses, purata masing masing adalah 6.24mm (SP-1.61), 7.06mm (SP-2.92), dan 4.95mm (SP-2.97). Tidak terdapat perkaitan penting ditemui diantara isipadu ANC dengan ketebalan paruh frontal, panjang A-P frontal ismus dan frontal reses.

Kesimpulan: Ketebalan paruh frontal tidak berkait dengan isipadu Agger Nasi sel. Tiada kesan atau kaitan yang penting terhadap nilai jarak panjang frontal ismus dan frontal reces terhadap isipadu Agger Nasi sel (semua nilai $p > 0.05$)

Kata kunci: Paranasal sinus, Agger Nasi sel, paruh frontal, frontal ismus, frontal reses, imbasan tomografi, pembedahan navigasi endoskopi

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

ABSTRACT

Introduction: The frontal sinus has the most complex and variable drainage of any paranasal sinus. Its outflow tract and anatomical structure is critical for safe endoscopic navigation during functional endoscopic sinus surgery. It includes the frontal infundibulum, ostium and recess in the direction of the drained secretion. The actual course may vary depending on pneumatization pattern of surrounding bones. The agger nasi cell (ANC) as most commonly found in population plays crucial role as anatomical landmark for the recess. Its volume is related to frontal beak (FB) thickness, frontal isthmus (FI) and frontal recess (FR) length. The purpose of this study is to determine correlation of ANC volume with the FB thickness, FI and FR length in adult patient in Hospital Universiti Sains Malaysia (HUSM), based on the fact that there is significant correlation of volume of ANC with the FB thickness, FI and FR length.

Methodology: A cross sectional study was conducted in 140 adult patients aged above 18 years old with no previous history of paranasal sinuses surgery who had CT Brain done in HUSMfrom January 2010 to June 2018. 3-dimensional (3D) images were constructed using Multiplanar Reconstructed (MPR) technique from thin-sliced (1mm) image of CT brain. The coronal and parasaggital view clearly showed frontal sinus cells, pneumatisation pattern,

location and variants. The measurement of Agger Nasi cell volume, frontal beak thickness, frontal recess and frontal isthmus length were performed using facial bone review of high kernel algorithm. Correlation between volume of agger nasi cell with frontal beak thickness, A-P length of frontal isthmus and frontal recess determined using Pearson correlation test.

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

Conclusion: Thickness of FB did not correlate with volume of ANC and no significant correlation with A-P length of FI & FR with volume of ANC.

Keywords: Paranasal sinus, Agger Nasi cell, Frontal Beak, Frontal Isthmus, Frontal recess, computed tomography, multiplanar reconstruction, functional endoscopic sinus surgery

CHAPTER 1 : INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background

Frontal sinus outflow tract (FSOT) or synonymously known as frontal recess (Huang et al., 2009) is the space through which the frontal sinus drains. It is complex bony anatomical configuration which highly variable and need complete understanding before any surgical intervention done. It is a complex space with the shape resembling inverted funnel hourglass appearance which its 'waist' demarcates the level of frontal sinus floor. Its variable anatomy is determined by the pneumatisation pattern of frontal recess cell. The latest classification currently used is modified Kuhn classification which allows accurate characterization and configuration to be understood by surgeons.

Building Block Concept is a 3 dimensional (3-D) anatomic reconstruction of the anatomy of the frontal recess. Through this concept, the preliminary idea can help surgeon which cell is being dissected and in what sequence each cell will be opened so that frontal recess can be safely and competently cleared.

Radiographic delineation of this paranasal sinuses region, provides preoperative information regarding morphology and pathology which lead to more focused endoscopic surgery. The frontal recess or outflow tract can be explored in a predetermined sequential manner to clear the obstruction in the outflow tract. Familiarity of these microanatomic locales by radiologist is crucial to differentiate

between normal and disturbed anatomy and also allows otolaryngologist to be able to turn to the CT scan images at any point during the dissection and identify the cell that is currently being dissected.

The main purpose of functional frontal sinus surgery(FESS) is to remove any anatomical obstructions and improve the mucociliary clearance along the sino-nasal physiological pathways. Currently, endoscopic sinus surgery is a common operation which is proven to be very useful for treating frontal sinus disease and it is accepted as the treatment of choice for frontal sinus condition with reported success rates as high as 98% for primary intervention and 78% for revision cases. However, in view of complex anatomical landmark, FESS is most likely to fail due to inadequate removal of cells obstructing the outflow of the frontal sinus. In the latest approach, agger nasi cell is used as the main landmark to understand the anatomy of frontal recess instead of using the uncinate process as frequently used in the past.

Acute rhinosinusitis is defined as mucosal inflammatory disease of the paranasal sinuses and nasal cavity. The FSOT is the most common region where disease recurrence occur. The obstruction at the level of frontal recess is the main cause of medically refractory disease. Anteriorly located and tight confinement between the orbit and anterior skull base make the frontal recess a notoriously difficult area to treat with endoscopy. It remains as one of the areas of the nose that often causes confusion among the surgeons. This makes it the most common area for the recurrence of sinus disease because surgeons tend to have poor confidence exploring this area, leading to inadequate removal of the disease.

Close proximity of frontal recess to anterior ethmoid artery, orbit and anterior cranial fossa can cause serious complication. It is also susceptible to post operative scarring, leading to frontal recess stenosis and disease recurrence. Adequate exposure is necessary to produce effective frontal sinus surgery. In case of more advanced disease, it may require surgical enlargement of frontal sinus outflow tract. The frontal recess is enlarged in the anterior posterior dimension through the clearance of agger nasi cells to maximize exposure of the frontal recess. It is not actually enlarging the frontal ostium, but enlarging what may be the narrowest point of the recess, particularly those with well pneumatised agger nasi cells. This procedure reported to have up to 86% success rate for patient with large, prominent agger nasi cell and appears to be effective in both primary and revision surgery of frontal sinusitis.

Previous studies showed moderate correlation ofvolume of agger nasi cell with Anterior-Posterior length of frontal isthmus and frontal recess but no significant correlation of volume of agger nasi cell with frontal beak thickness. This study aims to establish accurate data in Hospital Universiti Sains Malaysia and to compare the significant findings of similar correlation, as local data may be different due to discrepancy in socio-demographic and genetic factors.

1.2 Research Question

Does the volume of agger nasi cell affected by frontal beak thickness and its correlation to the length of frontal isthmus and frontal recess?

1.3 Objectives

1.3.1 General objective

Correlation ofthe volume of agger nasi cells with the frontal beak thickness and anterior-to-posterior length of frontal isthmus and frontal recess.

1.3.2 Specific objectives

1. To determine the pneumatisation variants of the frontal recess in adult population.
2. To correlate the volume of agger nasi cells with the thickness of the frontal beak.
3. To correlatethe volume of agger nasi cells with the anterior-to-posterior length of frontal isthmus and frontal recess.

CHAPTER 2 : LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Anatomy of the Frontal Sinus Outflow Tract and its variants

Frontal sinus outflow tract (FSOT) or synonymously known as frontal recess (FR)(Huang *et al.*, 2009) is the space through which the frontal sinus drains. It is complex bony anatomical configuration which highly variable and need complete understanding before any surgical intervention is done (Ximendes *et al.*, 2018). Its complex space and shape resemble an inverted funnel hourglass appearance and 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 frontal recess cell or synonymously known as anterior ethmoid cell (Lee *et al.*, 2004). The proposed concept of anatomic variability was introduced since last century and since then, its pneumatisation pattern was extensively described by many authors. The latest classification for its variant and pneumatisation patterns, is the modified Kuhn classification (Lee *et al.*, 2004). This classification which include the agger nasi cell (ANC), frontoethmoid cells type 1-4, supraorbital ethmoid cells, supra bullar cells, frontal bullar cells and interfrontal sinus septal cells allows accurate characterization and configuration to be understood by surgeons. The tract is basically bounded anteriorly by the ANC, laterally by the orbit and medially by the the middle turbinate. Posteriorly the tract depends on skull base structure which is ethmoid bulla or bulla lamella (Smith *et al.*, 2001).

2.2 Pneumatisation variants of frontal recess cells

FR isthe one of the most challenging areas to otorhinolaryngologist due to its variable anatomy. Several studies and classifications have been described before to help and guide the surgeon the most ideal technique on how to approach this area. The most widely and currently accepted is modified Kuhn classification.

2.2.1 Modified Kuhn classification of frontal recess cells

The first cell in the classification is ANC which is present in almost 90% of the population in most of the studies (Park *et al.*, 2010), (Ahmet Altıntaş *et al.*, 2017) and (Makihara *et al.*, 2019). It is defined as pneumatisation of the agger nasi region and the most anteriorly located ethmoid air cell. The second most common is frontoethmoid cells which is single anterior ethmoid cell that is associated with frontal process of maxilla and sit on top of agger nasi cell with 4 subtypes; 1, 2, 3 & 4 (Wormald, 2005). Some literatures give different nomenclature such as frontal cell (Lee *et al.*, 2004) and supra agger cell (Tran *et al.*, 2019). Supraorbital ethmoidal cell (SOEC) is defined as pneumatisation of orbital plate of frontal bone. It may mimic the appearance of septate frontal sinus which can be seen extending over the orbit from the frontal recess. The fourth cell in the classification is suprabullar cell (SBC) which can be found above the ethmoidal bulla in the posterior frontal recess with its superior wall being the anterior cranial fossa skull base. Once it is seen to extend and pneumatise along the skull base into the frontal sinus superiorly, it is called frontal bullar cell (FBC).The last cell in this classification is interfrontal sinus septal cell (IFSS) characterized by pneumatisation of

the interfrontal sinus septum and its associated with pneumatised crista galli (Lee *et al.*, 2004) as in ***Figure 1 (A-F)***

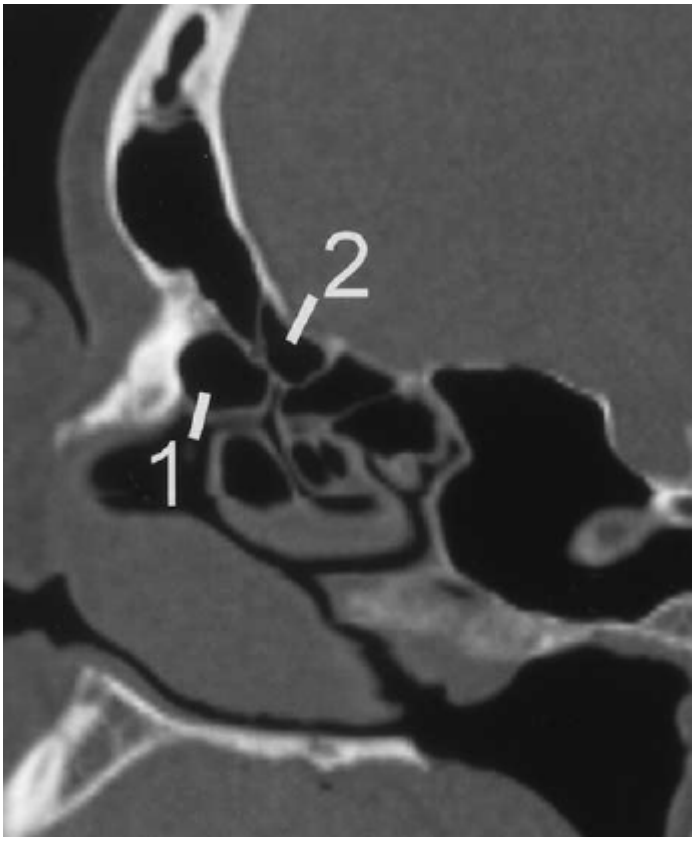

Figure 1 : Frontal recess cells : agger nasi and suprabullar cell.

Agger nasi cell (1) is the most anterior ethmoid air cell which forms part of anterior borders of frontal recess. Suprabullar cell (2) at the anterior cranial fossa skull base which forms part of posterior border of frontal recess.

(Adapted from Lee *et al*, 2004)

Figure 2 : Frontal recess cell :Type 1 frontoethmoid cell

Coronal CT image demonstrates type 1 frontoethmoid cell (*) above the agger nasi cell

(Adapted from Lee *et al*, 2004)

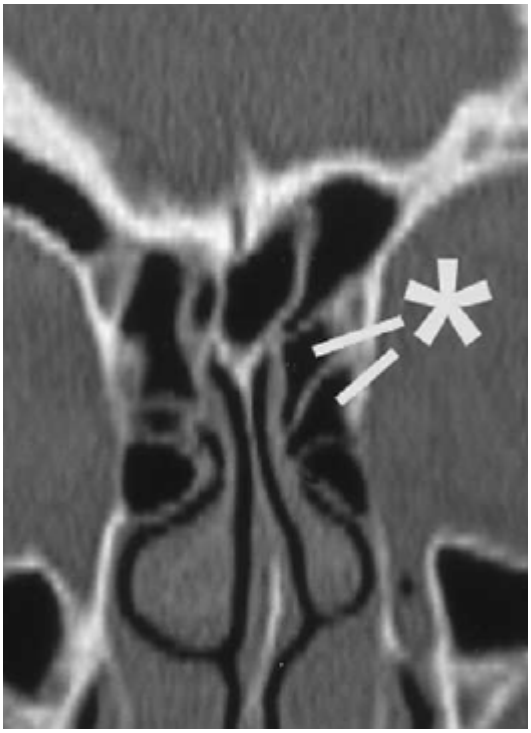

Figure 3 : Frontal recess cell : Type 2 frontoethmoidal cell.

Coronal CT image demonstrates type 2 frontoethmoid cell, above agger nasi cell

(Adapted from Lee *et al*, 2004)

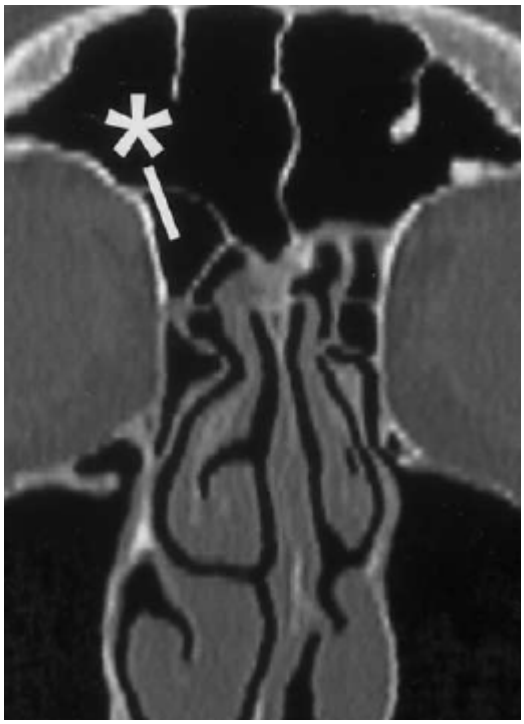

Figure 4 : Frontal recess cell : Type 3 frontoethmoidal cell

Coronal CT image demonstrates type 3 frontoethmoid cell (*) above agger nasi and enters the true frontal sinus.

(Adapted from Lee *et al*, 2004)

Figure 5 : Frontal recess cell : Frontal bullar cell

Sagittal CT – indicated by *, frontal bullar cell pneumatizes extending along the skull base and enters the true frontal sinus.

(Adapted from Lee *et al*, 2004)

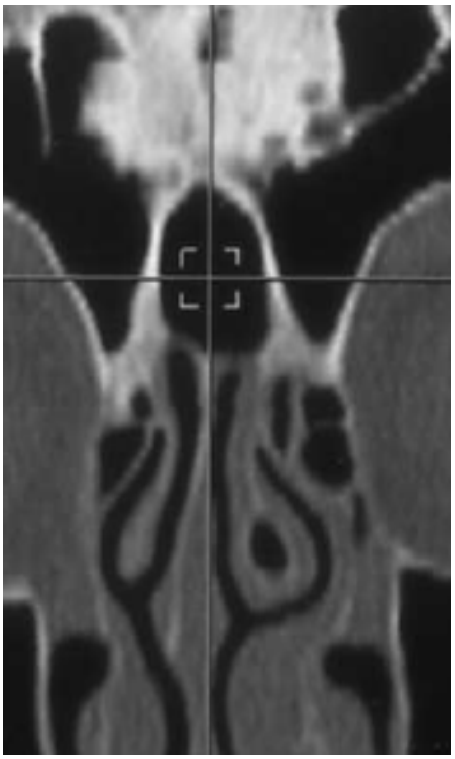

Figure 6 : Frontal recess cell : Interfrontal sinus septal cell (IFSS)

Coronal CT image demonstrates interfrontal sinus septal cell at the center of cross line, pneumatises within frontal bone.

(Adapted from Lee *et al*, 2004)

2.2.2 3 Dimension Concept of Analysis of Frontal Recess & Sinus Anatomy

Building Block Concept (Figure 7) is a 3 dimensional (3-D) anatomic reconstruction of the anatomy of the frontal recess. It was proposed by (Wormald, 2006) for better understanding of this complex anatomical region. Building blocks are arranged, one block for each cell, which begins with the ANC. Through this concept, the preliminary idea can help surgeon which cell is being dissected and in what sequence each cell will be opened so that frontal recess can be safely and competently cleared. This cell is easily identified as a single cell anterior to the middle turbinate which is best seen on coronal and parasagittal views. Once it is identified, the next step is to identify frontoethmoidal cell which is one of the cells commonly associated with ANC. A further building block is placed adjacent to the ANC block (cell number 2) for each additional cell seen. This figure demonstrates frontoethmoid cell (cell number 1 and 3)pneumatising through frontal ostium into frontal sinus. Small intersinus septal cell labelled as cell number 4. The frontal beak as seen extending on top of cell number 1 and 2, its thickness may affect the volume size of ANC, as well as the length and width of frontal recess. This 3-D image is best seen in coronal and parasaggital view by multiplanar reconstruction (Wormald, 2005)

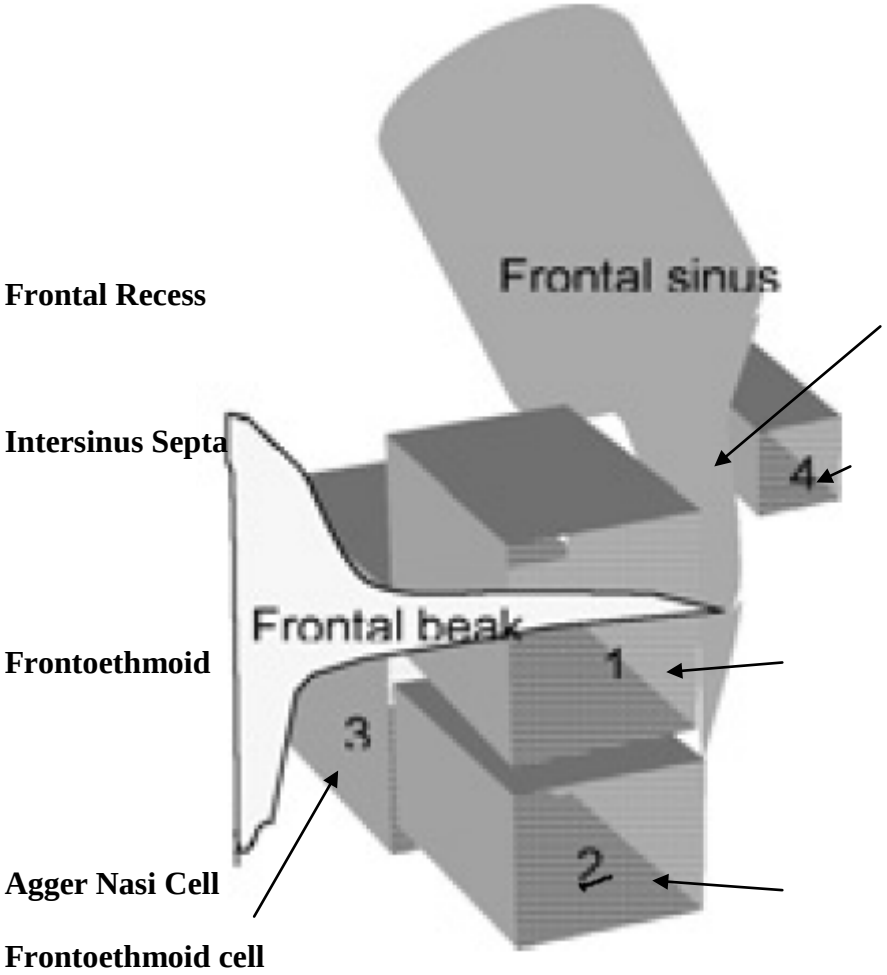

Figure 7 : Building block concept of frontal recess and sinus anatomy

(Adapted from Wormald, 2005)

2.3 Paranasal Sinus – Goal of Current Treatment

Most of paranasal sinus are treated symptomatically whilst rhinosinusitis being the most common disease for paranasal sinus is treated medically. Recurrent rhinosinusitis, however may require surgical exploration to clear the pathway or tract.

2.3.1 Paranasal Sinuses Disease - Medical Treatment &Endoscopic diagnosis

Acute rhinosinusitis has been defined by the American Academy of Otolaryngology Task Force on Rhinosinusitis as a mucosal inflammatory disease of the paranasal sinuses and nasal cavity(Husain *et al.*, 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 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 the symptoms necessitating referrals to rhinologists for consideration of surgical treatment (Maccabee and Hwang, 2001).

In addition, up to 23% of the patients need secondary or revision surgery for recurrent or continued symptoms after initial surgery. The frontal sinus outflow tract is the most common region where disease recurrence occur. The obstruction at the level of

frontal recess is the main cause of medically refractory disease (McLaughlin *et al.*, 2001).

Anteriorly located and tight confinement between the orbit and anterior skull base make the frontal recess a notoriously difficult area to treat with endoscopy. It has been reported to have significant predilection for stenosis after endoscopic intervention (Kuhn and Javer, 2001).

2.3.2 Surgery of Frontal Recess and Frontal Sinus

The frontal recess (FR) or sinus outflow tract and sinus anatomical structures are extremely complex(Huang *et al.*, 2009). The frontal sinus is the most likely area for the failure of endoscopic sinus surgery because of the difficulty in detecting the anatomical landmarks (Makihara *et al.*, 2019). It remains as one of the area of the nose that confused the surgeons and it is the most common area for the recurrence of sinus disease because surgeons tend to have poor confidence exploring this area, causing inadequate removal of the disease (Peter, 2003).

Close proximity of FR to anterior ethmoid artery, orbit and anterior cranial fossa can predispose to serious complication. It is also susceptible to post operative scarring, leading to FR stenosis and disease recurrence. Adequate exposure is necessary to produce effective frontal sinus surgery. For non-complicated anterior ethmoid sinus disease (which may or may not involve the frontal sinus), the surgical dissection or intervention is directed at the anterior ostiomeatal complex. Combination of

uncinectomy, anterior ethmoidectomy and middle meatal antrostomy are sufficient to clear the diseases in the frontal sinus and FR(Daniels *et al.*, 2003).

In case of more advanced disease, it may require surgical enlargement of frontal sinus outflow tract. The FR is enlarged in the anterior posterior dimension through the clearance of ANC(Pletcher *et al.*, 2006). The new technique of agger nasi Punch-Out Procedure (POP) introduced by Pletcher (2006) is to maximize exposure of the frontal recess. It is not actually enlarging the frontal ostium, but enlarging what may be the narrowest point of the recess, particularly those with well pneumatisedANC. It provides the surgeon with improved exposure for identification and enlargement of frontal sinus ostium. The surgeon, later can operate with 0 degree endoscope, avoiding 30 degree endoscope which added the challenges of working around corners. This procedure reported to have up to 86% success rate for patient with large, prominent ANC and appears to be effective in both primary and revision surgery of frontal sinusitis (Pletcher *et al.*, 2006).

2.3.3 Priciples of Functional Endoscopic Sinus Surgery (FESS)

The main purpose of FESS 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). Systematic endoscopic exploration of lateral nasal wall was pioneered by Prof. Messerklinger which detailed the endoscopic anatomy and pathology of this region. It was later, modernized by David Kennedy and Karl Storz of Johns Hopkins University by developing instruments for use in endoscopic sinus surgery and invented the term Functional Endoscopic Sinus Surgery

(Tajudeen BA et al, 2017). It aims to return the working of the sinuses to normal, hence it is called functional (Head and Neck, East Kent Hospitals, 2019).

Currently, endoscopic sinus surgery is a common operation which is proven to be very useful in treating frontal sinus disease and has been accepted as the treatment of choice for frontal sinus condition (Takasaki *et al.*, 2010) with reported success rates as high as 98% (Huang *et al.*, 2009) for primary intervention and 78% for revision cases (Maccabee and Hwang, 2001). However, dealing with the most difficult area in detecting the anatomical landmark, endoscopic sinus surgery is more likely to fail due to inadequate removal of cells obstructing the outflow of the frontal sinus (Makihara *et al.*, 2019). In the latest approach, ANC is used as the main landmark to understand the anatomy of FR instead of using the uncinate process as in the past (Peter, 2003).

2.4 Agger nasi cell (ANC) – The key that unlocks the frontal recess

The outflow tract of the sinus is bounded anteriorly by ANC and frontal beak (FB). Being the most commonly found structures in the population, understanding of its anatomy greatly facilitates the surgical approaches to the frontal sinus.Pletcher *et al.* (2006) introduced a technique called agger nasi (POP) to improve the exposure and enlargement frontal recess with success rate up to 90%.Peter (2003) stated that large ANC reduces the thickness of FB while Park *et al.* (2010) and Makihara *et al.* (2019) found that no correlation at all between the volume of ANC and FB thickness. While for frontal isthmus(FI) and FR, Ahmet Altıntaş *et al.* (2017) has acknowledged that there is no correlation between volume of ANC with A-P length of the FI and FR. Understanding of these correlation may guide surgeon for pre operative planning.

2.5 Role of Radiologist in Reporting the Paranasal Sinus Computed Tomography

Computed Tomography (CT) is widely utilized as an essential imaging tool in the diagnosis and evaluation of bony pathology in patients. The principles behind it are the use of x-rays to build cross-sectional images (slices) of the body. In the early invention of CT, it provides axial view of the scanned images. The fundamental principle is that the density of the tissue which the x-ray beam pass can be measured from the collective data of attenuation coefficient. It then allows the reconstruction of the density of the body by two dimensional section perpendicular to the axis of the acquisition system. In the modern era, this cross sectional or axial view of the study is later reconstructed from the raw data of the images acquired from traditional axial plane using complex mathematical algorithms to produce 3-D images. This process is known as multiplanar reconstruction (MPR) study.

The advantages of CT in comparison to conventional radiograph are the non overlapping images, better spatial resolution, greater bony structures details and ability to reconstruct the overlapping and different density of soft tissue into single image (Rydberg *et al.*, 2000)

The latest high-resolution multidetector computed tomography (MDCT) imaging with thin slice capability has advanced our understanding of sinonasal anatomy and physiology, and was imperative to pre operative planning of FESS. The important information that should be concentrated from detailed sinus CT analysis includes the extension and characterization of the disease, location of surgically relevant anatomic

structures, and the identification of critical anatomic variations which are very crucial to the surgeon.

One study reported that majority of otolaryngologists are not really satisfied with CT radiologic reporting and would like to have more radiological and clinically relevant information. High variability CT reports with many critical and noncritical items are infrequently reported by most radiologists. A standardized CT radiologic template and guidelines 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(Deutschmann *et al.*, 2013)

Radiographic delineation of this paranasal sinuses region, provides preoperative information regarding morphology and pathology which lead to more focused endoscopic surgery. The frontal recess or outflow tract can be entered in a predetermined sequential manner and then, removed 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 differentiate between normal and disturbed anatomy (Kennedy and Rosenbaum, 1987) and also allows 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.

2.6 Rationale of Study

Sometimes, the complexity of the anatomy of the FR causes hesitation or lack of confidence among the surgeons when approaching the frontal sinus and its outflow tract. This study evaluated the pneumatisation patterns of FR in population specifically patients in HUSM. The aim of this study is to examine the relationship between the FR width and the ANC size as well as FB thickness in patients since the success of endoscopic frontal sinus surgery may be influenced by the width of the frontal recess. Radiology team in HUSM plays significant role in reporting and assisting surgeon to guide clear anatomical configuration of the sinus pathway as part of pre-operative plan to reduce the risk of perioperative adverse event and post operative complications.

CHAPTER 3 : METHODOLOGY