

UTILITY OF MULTIPLANAR RECONSTRUCTED

(SAGITTALLY REFORMATTED)

COMPUTED TOMOGRAPHY

IN THE EVALUATION OF

FRONTAL SINUS OUTFLOW TRACT (FSOT)

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VELLORE, TAMILNADU, INDIA

DISSERTATION SUBMITTED IN PART FULFILLMENT OF THE

RULES AND REGULATIONS FOR THE M.S. (BRANCH IV)

OTORHINOLARYNGOLOGY EXAMINATION OF THE

TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY TO BE HELD IN MARCH 2008

CERTIFICATE

This is to certify that the dissertation “ **UTILITY OF MULTIPLANAR
RECONSTRUCTED (SAGITTALLY REFORMATTED)
COMPUTED TOMOGRAPHY , IN THE EVALUATION OF FRONTAL SINUS
OUTFLOW TRACT (FSOT)** “ is a bonafide work of Dr.James Albert Jaganath
carried out under my guidance, for the M.S. (BRANCH IV) Otorhinolaryngology
examination of the Tamilnadu DR.MGR medical university to be held in march 2008.

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ACKNOWLEDGEMENTS

This study was possible because of the blessings of God, the unseen hand that supported me in each step.

I wish to express my deep gratitude to **Dr. Anand Job**, Professor & Head of the Department of Otorhinolaryngology, Speech & Hearing and Head & Neck Surgery, Unit I , Christian Medical College & Hospital, Vellore, for his able guidance & encouragement in conducting this study and also being my guide and for his constant support in preparing the Dissertation.

I am extremely grateful to **Dr.Arif Ali.K**, and **Dr.Kuldeep Moras**, Department of Otorhinolaryngology, Speech & Hearing and Head & Neck Surgery, and **Dr. Joe Prathip**, Department of Radio-diagnosis, CMC Hospital, Vellore, for being my Co- investigators in this study and their valuable help.

I am extremely thankful to **Dr. V. Rupa**, and **Dr. John Mathew**, Department of Otorhinolaryngology, Speech & Hearing and Head & Neck Surgery, CMC Hospital, Vellore, for their valuable advices and help.

I am expressing my gratitude to **Dr. Selvaraj**, Professor, Department of Biostatistics, for his guidance in statistical analysis.

I wish to thank the ***Fluid Research Committee***, CMC, Vellore for granting me financial assistance for conducting the study.

Last, but not the least, I wish to thank all my colleagues and staff of ENT for their help in making this study a reality.

CONTENTS

	Page No.
1. INTRODUCTION	---- 8
2. AIMS	---- 10
3. REVIEW OF LITERATURE	---- 11
4. MATERIALS AND METHODS	---- 41
5. RESULTS	---- 45
6. DISCUSSION	---- 73
7. CONCLUSIONS	---- 82
8. BIBLIOGRAPHY	---- 85
9. APPENDIX - PROFORMA	---- 87

INTRODUCTION

Accurate diagnosis of chronic sinusitis has remained a challenge. History, clinical examination, endoscopy and radiology need to be combined to make a complete diagnosis. Imaging also has resulted in improvement in techniques of surgery as anatomical variations have been better diagnosed. Computer Tomography of the paranasal sinuses classically has been performed with coronal 3mm slices to provide single plane of morphologic depiction of sinus anatomy for presurgical mapping and evaluation. Recent advances in computer tomography provide multiplanar 1mm reconstructed images (axial, coronal and sagittal) of frontal sinuses and their corresponding drainage pathway.¹

The complex and variable anatomy of the frontal recess can be difficult to appreciate with standard axial or coronal CT images of the sinus.

The advent of multiplanar CT imaging with addition of sagittal reconstructions greatly improves the understanding of the frontal recess. In addition to the inherent variation in size and diameter, the presence of various accessory cells such as frontal cells and intersinus septal cells also contribute to the anatomic complexity of the frontal recess and the potential for obstruction of the frontal sinus. Persistence of anatomic causes of obstruction of the frontal recess has been reported as a major cause of failure of endoscopic sinus surgery.

The purpose of this study is to determine the prevalence of frontal cells and to establish the advantages of reconstructed images over plain images in the assessment of Frontal Sinus Outflow Tract

Chronic frontal sinusitis represents perhaps one of the most difficult areas within the paranasal sinuses to manage. Patients with chronic frontal sinusitis frequently have associated disease in the remaining paranasal sinuses. Isolated frontal sinus disease occurs rarely. Symptoms for 3 months or more is considered as chronic sinusitis. Symptoms are not generally sensitive or specific for uncomplicated frontal sinusitis.¹

The frontal sinus and its drainage pathway comprise one of the most complex anatomic areas of the anterior skull base. Its complexity is magnified by the frequency of anatomic variations which impact the direction of drainage , efficacy of mucociliary clearance and morphology of frontal recess.

Recent advances in Computer Tomography especially the multiplanar reconstruction has made demonstration of this complex anatomy easier and more useful to rhinological surgical approach.¹

This study utilizes multiplanar reconstructed Computer tomography images in the evaluation of frontal sinus outflow tract.

AIMS

1. To determine the prevalence of frontal recess cells by analyzing reconstructed Computed Tomography of Frontal Sinus Outflow Tract (FSOT) in normal population and in patients with chronic rhinosinusitis

2. To evaluate the role of these accessory cells in the pathogenesis of Chronic Frontal Sinusitis.

3. To establish the advantages of reconstructed Computer Tomography images over plain images in the assessment of Frontal Sinus Outflow Tract

REVIEW OF LITERATURE

Surgical Anatomy of the frontal sinus

Volcher Coiter of Holland , a pupil of Fallopius and Eustachius, is said to be the first to describe the frontal sinus (1981).

Berengario de carpi described the frontal bone region as having “ two tables within which there is a notable vacuity so as to not to weigh down the body”(1522). Leonardo de Vinci in 1489 may have been the first to recognize its existence and illustrate its morphology.²

Frontal Recess was first described by Killian in 1903. Later Van Alyea’s writings extensively described the pneumatization patterns within the frontal recess. ⁴

Synonyms of frontal recess are “nasal part of frontal sinus”, “frontal infundibulum”, “nasofrontal duct”. ⁵

Coronal Computed tomography analysis of frontal cells

‘Meyer et al’ determined the prevalence of frontal cells and other anatomic variants and examined their relationships in a study of 768 coronal CT scans.

They concluded that , 1: The prevalence of frontal cells among a population undergoing computed tomography is 20.4 % with type 1 cells being most common (14.9 %).

2: Frontal cells are associated with other anatomic variants.

3: Presence of frontal cells does not invariably lead to frontal sinusitis

but may contribute to the mechanical obstruction of frontal recess.

4: Prevalence of frontal mucosal thickening was increased in

individuals with type 3 and type 4 cells compared to individuals without frontal cells

($p < 0.01$) **9**

Multiplanar reconstructed CT in depiction of anatomy of frontal sinus

'Kew et al' assessed the use of multiplanar reconstructed computer tomography images of frontal recess and sinuses with regard to depiction and understanding the anatomy and effect on surgical approach in 43 patients. There was no statistically significant difference between the Bent and Kuhn classification of frontoethmoidal cells on coronal and parasagittal images ($p > 0.05$). The three dimensional understanding of the frontal recess is greatly improved by using both coronal and parasagittal reconstructed images as compared to coronal images alone ($p < 0.001$) This had important implications on the planning of the surgery in frontal recess. **10**

Three dimensional computed tomography analysis of frontal recess anatomy in patients without frontal sinusitis

'Walter T Lee et al' described frontal sinus pneumatization in 50 patients with no history of frontal sinus disease using 3 dimensional computed tomography. The prevalence of each structure was

Agger nasi cell : 89 %

Type 1 frontal cells : 37 %

Type 2 frontal cells : 19 %

Type 3 frontal cells : 8 %

Type 4 frontal cells : 0%

Supraorbital ethmoidal cell : 62 %

Suprabullar cell : 15 %

Frontal bullar cell : 9 %

Interfrontal sinus septal cell : 14 %

Recesses terminalis : 22 %

This study describes frontal pneumatization in patients without a history of conditions that influence frontal pneumatization. **11**

Multiplanar computed tomography analysis of frontal recess cells

‘DelGaudio et al’ determined the prevalence of frontal recess cells and their relationship to frontal sinusitis using multiplanar reconstructed CT images in 106 patients.

Frontal cells were found in 33 % patients, with an equal number of unilateral and bilateral frontal cells.

Type 1 cells were the most common (18.4 %)

Type 2 cells in 2 % of cases

Type 3 cells in 6.1 % of cases

Type 4 cells in 3.1 % of cases.

The presence of frontal cells did not correlate with a greater incidence of frontal sinusitis in this series.¹³

This finding is in contrast to the data from Meyer et al who found a higher incidence of frontal sinusitis in patients with type 3 and type 4 cells. ⁹

‘Van Alyea’ found a 40 % incidence of frontal cells, but this likely included supraorbital ethmoid cells, agger nasi cells, and intersinus septal cells, possibly making this figure much higher than the actual incidence. ¹⁴

‘Meyer et al’ showed that 20.4 % of patients had frontal cells on review of 768 coronal CT images with type 1 cells being most common (14.9%), type 2 cells in 1.7% and type 4 cells in 3.1 % of patients.⁹

The presence of frontal cells did not correlate with a greater incidence of frontal sinusitis in this series. There was no association between the size of the frontal isthmus and the presence of frontal sinusitis. Agger nasi cell was present in 86.7 % of cases. Interfrontal septal cells were present in 12.2 % cases. No difference was found in the presence of frontal sinusitis with respect to the presence of agger nasi cells.¹³

Role of agger nasi cell in chronic frontal sinusitis

Agger nasi is the most constant and anterior of the ethmoid cells. In 1942 Van Alyea reported it in 89 % of patients. Recently Bolger et al reported it in 98.5 % of patients. It is bordered by

the frontal process of maxilla anteriorly , frontal sinus and frontal recess superiorly, nasal bones anterolaterally , lacrimal bone inferolaterally, uncinate process inferomedially, and by ethmoid infundibulum posteriorly.

Stammberger and Wolf and Kuhn et al described its location as anterior and superior to the insertion of middle turbinate on lateral nasal wall. Kennedy and Zinreich stated that agger nasi cell is located below frontal sinus.¹² 'Brunner et al' reviewed the surgical outcome and CT images in 26 patients with chronic frontal sinusitis and suggested that agger nasi cell pneumatization with narrowing of the frontal sinus outflow tract is a significant cause of persistent frontoethmoid pain and chronic frontal sinusitis.

Sagittal reformatted images , in comparison to coronal plane images, are superior in demonstrating agger nasi cell encroachment on the nasofrontal duct, as well as nasofrontal duct mucosal disease.

Sagittal images are important in preoperative planning to define the course of nasofrontal duct.

Endoscopic frontal sinusotomy is an effective treatment for chronic frontal sinusitis.

Frontal sinus is an anterior ethmoid cell which has grown into the frontal bone. This growth begins in the second trimester of fetal life and continues into adolescence. The size of frontal sinus varies significantly ranging from aplasia to near total aeration of the frontal bone. From one to four frontal pits grow cephalad from the middle meatus to form the anterior ethmoid cells and pneumatize each half of the frontal bone, generally the second frontal pit becomes the frontal sinus. Other frontal pits that do not become the frontal sinus may develop into

agger nasi cells, frontal cells, supraorbital cells or intersinus septal cells. These cells may become primarily infected or obstruct frontal sinus drainage.**3**

The adult frontal sinus when viewed in transverse section, has been classically described as pyramidal shaped (Mosher-1904). The base or floor of the pyramid is the orbital nasal portion of the splanchnocranium; the apex extends outwards a variable distance over the orbit, and the anterior wall is subcutaneous whereas the posterior wall is cerebral (Radoievic-1958). Dimensions of the frontal sinus have been reported as measuring 28mm in height, 27mm in width , and 17mm in length (Maresh-1940).

At the inferior aspect in the midsagittal plane, the anterior or outer table of the frontal sinus is approximately twice as thick as the posterior, or inner table.

The sinus is compartmentalized further by the intrasinus septa and margined by irregular bone. The frontonasal outflow tract has been likened to an hourglass with the upper portion being the body of the frontal sinus, the neck being the ostium (2 – 10 mm in diameter), and the frontal recess representing the lower portion beneath the neck.**2**

The frontal sinus shares a common embryological and anatomical relationship with the ethmoid sinus, to the point that several authors and researchers have referred to this as a large ethmoidal cell or simply the termination or upper limit of the intricate ethmoid labyrinth.**9**

In an adult, two frontal sinuses are usually seen. Each frontal sinus cavity takes on the shape of a pyramid, with a thick anterior table and a thinner posterior table.

The anterior wall of the frontal sinus begins at the nasofrontal suture line and ends below the frontal bone protruberence, along the vertical portion of the frontal bone. The height of the cavity at its anterior wall ranges from 1 to 6 cm, depending on the degree of pneumatization. It is made up of thick cortical bone measuring an average of 4 to 12 mm in thickness. (**Fig . 1**)



Figure 1 – Lateral view of frontal sinus

The anterior table is covered by the pericranium (thick external periosteal layer), followed more superficially by the frontalis muscle, subcutaneous fat and skin. The posterior wall of the frontal sinus forms the most anteroinferior boundary of the anterior cranial fossa, and is in close contact with the frontal bones, separated only by the duramater. It has a superior vertical, and a small inferior horizontal portion. The horizontal portion will form part of the

orbital roof. Both posterior walls join inferiorly to form the internal frontal crest, to which the falx cerebri inserts.

A triangular shaped intersinus septum separates the frontal sinuses into separately draining sinus cavities. It is the continuation, anteriorly, of the fused and ossified embryological sagittal suture line.

Although the intersinus septum may vary in direction and thickness as it proceeds superiorly, the base of the intersinus septum will almost always be close to the midline at the level of the infundibulum. At this level, the intersinus septum is continuous with the crista galli posteriorly, the perpendicular plate of the ethmoid inferiorly, and the nasal spine of the frontal bone anteriorly. The falx cerebri inserts into the posterior table of the frontal sinus, at this point corresponding to the posterior edge of the intersinus septum. Additional intersinus septal cells may exist within this septum. Pneumatization from these intersinus cells may occasionally extend all the way into the crista galli.

These cells tend to drain into the nose through their own outflow tract, adjacent to the normal frontal sinus outflow tract, at the level of infundibulum on one or both sides of the nose.

Inferiorly the frontal sinus cavity is limited by the supraorbital rim and wall (or roof), through which the supraorbital neurovascular pedicle courses towards the forehead skin via the supraorbital foramen.

At this level, the frontal sinus is funnel shaped, forming the base of a pyramid. With the exception of the thin septations of the ethmoidal cells, this inferior wall of the frontal sinus makes up one of the thinnest walls of all the sinus cavities. Laterally the cavity extends itself

as far as the angular prominence of the frontal bone. The superior border of the frontal sinus is non-pneumatized cancellous bone of the frontal bone.¹⁹

Frontal Recess

The frontal recess is an inverted funnel shaped space which connects the frontal sinus ostium to the middle meatus. The frontal recess is not universally defined.³

The frontal sinus outflow tract has an hourglass shape with its narrowest point at the level of the frontal recess.

The frontal recess is formed by the most inferior aspect of the frontal sinus. It has the form of a funnel that points towards the ethmoid in a posteromedial direction.

The angulation and maximum diameter of this funnel may vary greatly between patients or even between sides.¹⁹ (Fig . 2)

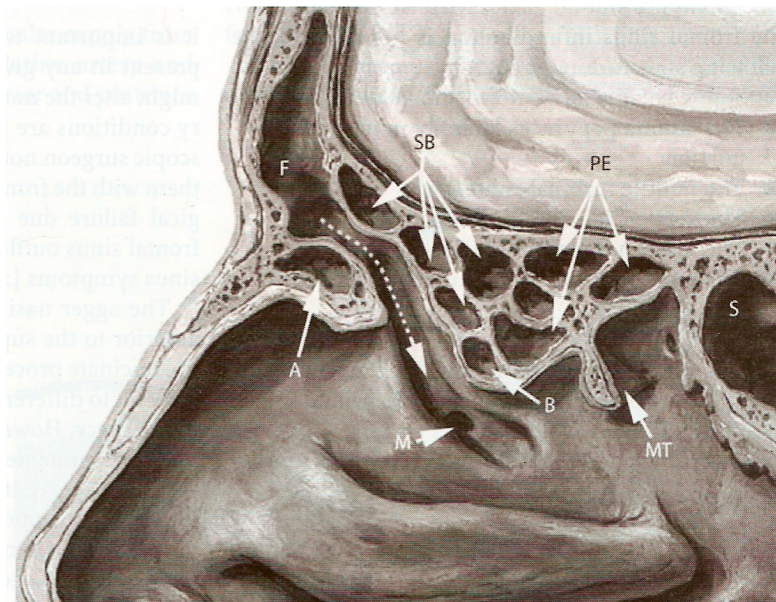


Figure 2 –

Hour glass – shaped frontal sinus outflow tract

The frontal sinus originates from the anterior pneumatization into the frontal bone.

The ostium of the frontal sinus is formed only when the frontal bone becomes attached to the ethmoid and when the immediate margins of the ostium of the frontal sinus are provided by parts of the ethmoid. In a sagittal section, there is an hourglass shaped structure, of which the narrowest part (the waist) is located at the frontal ostium and the lower part of which is designated as the frontal recess. Its limits, shape, and width are largely determined by the neighbouring structures.

Its medial border is almost always the lateral surface of the most anterior and superior portion of the middle turbinate. The lamina papyracea forms a large part of the lateral wall with its most anterosuperior extensions. If the ethmoid infundibulum has a terminal recess, the uncinate process forms part of the lateral wall and also contributes to the floor of the frontal recess in its most anterior aspects.

The roof is made up of those parts of the frontal bone that form the roof of the ethmoid with their ethmoidal fovea. The frontal ostium is usually found in the most anterosuperior part of the frontal recess. The posterior wall is formed by the ground lamella of the ethmoidal bulla. Depending on the position of the uncinate process the frontal recess opens into the middle meatus, medial to the uncinate and between this structure and the middle turbinate, or directly into the ethmoidal infundibulum.⁵

Frontal recess usually enters the middle meatus medial to the ethmoid infundibulum, either anterior (55% cases) or superior (30%) to the superior attachment of the uncinate process on the lateral nasal wall, occasionally, it drains directly into the ethmoid infundibulum (15%) or posterior to the uncinate process.³

The frontal recess is narrowed by forward extending and well developed bulla lamella, markedly pneumatized agger nasi, additional frontal ethmoidal cells, variation of the uncinate process, or conchabullosa of middle turbinate.⁵

Radiological anatomy of frontal sinus

Frontal sinus evaluation

Computed Tomography of the paranasal sinuses classically has been performed with coronal 3mm slices to provide single plane of morphologic depiction of sinus anatomy for presurgical mapping and evaluation.

Recent advances in computed tomography provide multiplanar 1mm reconstruction (axial, coronal and sagittal) of frontal sinus and their corresponding drainage pathway.¹⁹

Frontal sinus drainage pathway

The frontal sinus drainage pathway is the most complex of all sinuses, impacted by its anatomic relationships with the agger nasi, anterior ethmoid cells, and pattern of vertical insertion of the uncinate process. The frontal sinus grows and expands within the diploic space of the frontal bone from the frontal sinus ostium medial and superior to the orbital plates, enclosed anteriorly by the cortical bone of the anterior frontal sinus wall and posteriorly by the cortical bone of skull base and posterior frontal sinus wall. Each frontal sinus grows independently, with its rate of growth, final volume , and configuration dictated by its ventilation, drainage, and the corresponding growth (or lack of it) of the competing surrounding sinuses and skullbase.

The frontal sinus narrows down inferiorly and medially into a funnel shaped transition point , which is defined as the frontal sinus ostium, extending between the anterior and posterior frontal sinus walls at the skull base level. This point is typically demarcated along its anterior wall by the variably shaped bone ridge of the nasofrontal buttress frequently called the 'nasal beak'. The frontal sinus is oriented nearly perpendicular to the posterior wall of sinus at the level of the anterior skull base.¹⁹

The Anatomic Terminology Group defined the frontal recess as “the most anterior and superior part of the anterior ethmoid complex from where the frontal bone becomes pneumatized, resulting in a frontal sinus. In sagittal plane , the frontal recess frequently looks like an inverted funnel that opens superiorly to the frontal sinus ostium. The anatomic walls of the surrounding structures dictate its walls and floor. The frontal recess can be narrowed from the anterior – inferior direction by hyperpneumatized agger nasi cells. Its inferior drainage is dictated by the insertion of the vertical attachment of uncinate process, a sagittally oriented hook like bony leaflet. Whenever the uncinate process attaches to the skull base or the superior-anterior portion of the middle turbinate, the frontal recess drains into the the superior end of the ethmoidal infundibulum.

If the uncinate process attaches laterally into the lamina papyracea of the orbit, the frontal sinus opens into the superior aspect of the middle meatus, and the ethmoidal infundibulum ends blindly into a 'terminal recess'.¹⁹

Anatomic variants

Several important anatomic variants impact on the anatomy of the frontal sinus drainage pathways and the anterior skull base .

The frontal cells are rare anatomic variations of the anterior ethmoid pneumatization that impinge upon the frontal recess and typically extend within the lumen of the frontal sinus ostium above the level of the agger nasi cells.

Bent and Kuhn described four types of frontal cells.

Type 1 – a single cell above the agger nasi cell, which does not pneumatize into the frontal sinus.

Type 2 – a tier of cells above the agger nasi cell, which may or may not pneumatize into the frontal sinus.

Type 3 – a single massive cell above the agger nasi cell, pneumatizing cephalad into the frontal sinus.

Type 4 – single isolated cell within the frontal sinus , frequently difficult to visualize due to its thin walls (sinus within a sinus)

Supraorbital ethmoid cell : there is a pattern of pneumatization of the orbital plate of the frontal bone posterior to the frontal recess and lateral to the frontal sinus, frequently developing from the suprabullar recess. The degree of pneumatization of the suprabullar cells can reach the anterior margin of the orbital plate and mimic a frontal sinus. **19**

Physiology

The frontal sinus is the only sinus in which there is an active inwardly directed transportation of mucus. Along the interfrontal septum, mucus is transported into the frontal sinus, then laterally along its roof and back medially via the floor and inferior portions of the posterior and anterior wall of the sinus. The secretion then exits the frontal sinus via the lateral aspect of its ostium. Not all of this mucus leaves the sinus after one 'round trip'. This is the result of a whorl-like formation in the ciliary pattern, which may be present in a shallow sulcus immediately above the frontal ostium as well as inferior to it in the frontal recess. An unspecified amount of mucus comes into contact with the inwardly directed transport route again and thus may recycle through the sinus several times. 5 (Fig . 3)

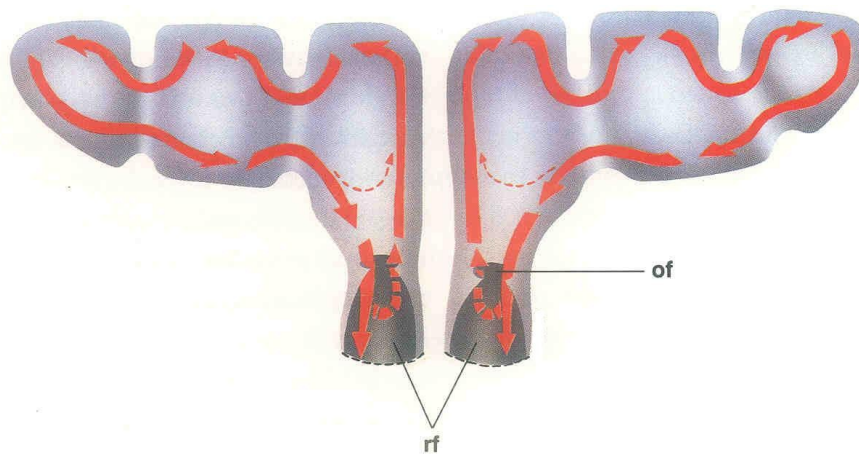


Figure 3 – Schematic diagram of secretion transport inside and out of the frontal sinus. (of – frontal sinus ostium, rf - frontal recess)

Once it has passed out of the ostium the secretion is then transported through a narrow cleft of variable dimensions, the frontal recess. This recess drains either directly into the ethmoidal infundibulum from above, or medial to the infundibulum if the infundibulum ends in blind pouch. The frontal recess, depending upon the prevailing anatomic variations, may collect the secretions from the ethmoidal compartments. Eventually the secretions from the frontal sinus merge with the secretions from the maxillary sinus and together they are transported back into the nasopharynx. **5**

The frontal sinus mucosa resembles the rest of the upper respiratory mucosa with its ciliated columnar epithelium, along the numerous glands and goblet cells that produce serous and mucinous glands. The frontal sinus mucosa is constantly producing secretions in order to ensure that the cavity is at all times cleared of particulate matter, and that proper humidification is achieved. Although the final destination of the secretions is the frontal recess, the secretions might recirculate several times through the entire frontal sinus cavity, via its intersinus or intrasinus septae before they finally make their way out into the nose through the frontal recess.¹⁹ The frontal recess connects internally with the inferior and medial region of the frontal sinus. This internal frontal sinus ostium is not always the most inferior or gravitationally dependent region of the frontal sinus.

However, the frontal sinus mucous membrane cilia transport the mucus blanket over the grooves and crevices of the sinus until it reaches the ostium. In 1932, Hilding demonstrated that the mucus blanket travels in a spiral towards the internal ostium in a way that effectively defies gravity. Messelkinger confirmed Hilding's work 35 years later; he made the additional

discovery that a portion of the mucus blanket actually recirculates within the frontal sinus and frontal recess while the remaining mucus enters the middle meatus. The frontal sinus has several hypothetical functions, it serves as a buffer for the brain in forehead trauma, contributes to forehead contour, reduces the weight of the skull, and adds resonance to the voice.

Mucociliary clearance mechanics help keep the sinus aerated and prevent airborne particulate contamination and fluid collection.³

Pathophysiology

Frontal sinusitis is directly related to either impaired mucociliary clearance or anatomic obstruction. Because the frontal sinus drains into the middle meatus via the anterior ethmoid system, the patency and lack of disease in this region is critical to normal frontal sinus function. Causes of frontal recess obstruction are aircells, soft tissue, postsurgical scarring, frontal and nasoethmoid trauma. Obstructing frontal recess cells are of anterior ethmoid origin, which include agger nasi cell, frontal cells, and supraorbital cells.

The agger nasi region is an eminence on the lateral nasal wall anterosuperior to the origin of middle turbinate. When pneumatized, this most anterior of the ethmoid cells is termed the agger nasi cell. It has been shown to be present in up to 98.5% of individuals. It may obstruct the inferior aspect of the frontal recess where it enters the middle meatus. The supraorbital cell aerates the orbital plate of the frontal bone, lateral and posterior to the frontal sinus. The supraorbital cell may either primarily opacify or obstruct the frontal sinus, leading to a secondary frontal sinus infection.

The frontal cell lies superior to the agger nasi cell and may impinge upon either the frontal recess or frontal sinus. Finally, large cells within the frontal sinus septum may block the internal ostium of the frontal recess. Other causes of obstruction of frontal recess are chronic inflammatory tissue, allergic fungal sinusitis, polyp formation, frontal sinus trauma, and iatrogenic factors. **3**

Failure to maintain the frontal sinus outflow tract patent (because of edema, fibrosis, polyps, and or neoplasm) may trigger a vicious cycle of events that results in retained secretions, secondary bacterial colonization ,hypoxia, pH changes, and ciliary dysfunction. Any or all of these physiological changes may culminate in chronic rhinosinusitis. **19**

Kuhn classified a number of cells that can lead to obstruction of the frontal recess and cause frontal sinusitis. These are namely frontal recess cells including agger nasi cell, supraorbital ethmoidal cells, frontal cells, frontal bullar cells, suprabullar cells, and interfrontal sinus septal cells. **6**

In addition to anatomical obstruction, mucosal obstruction of the frontal recess plays an important role in chronic sinusitis. **7**

There are also different factors such as hypoxia, dehydration, infection, foreign bodies, environmental irritants, trauma, tumour, and allergens that can affect the frontal sinus physiologic functions by disrupting the mucociliary clearance. **8**

(Fig . 4)

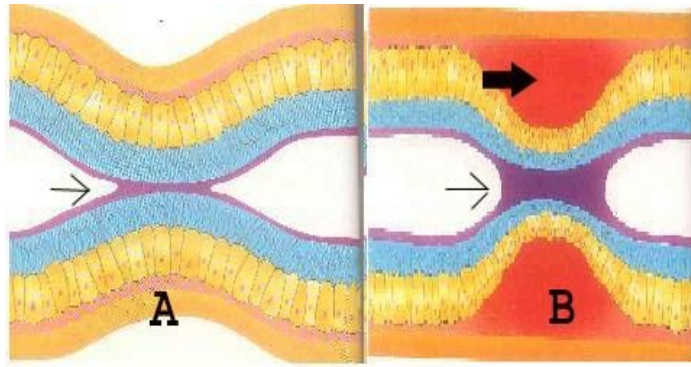


Figure 4 – A : Schematic diagram of normal healthy mucosa (thin arrow), with normal ciliary beat and mucus transportation

B – Diseased mucosa (thick arrow)

Multiplanar computed tomography analysis of frontal recess cells

The complex and variable anatomy of the frontal recess can be difficult to appreciate with standard axial or coronal CT images of the sinus.

The advent of multiplanar CT imaging with addition of sagittal reconstructions greatly improves the understanding of the frontal recess. In addition to the inherent variation in size and diameter, the presence of various accessory cells such as frontal cells and intersinus septal cells also contribute to the anatomic complexity of the frontal recess and the potential for obstruction of the frontal sinus.

Persistence of anatomic causes of obstruction of the frontal recess has been reported as a major cause of failure of endoscopic sinus surgery. The purpose of the study was to

determine the prevalence of frontal cells , to determine whether the presence of frontal sinus cells is related to the presence of frontal sinus disease.

Frontal sinusitis was considered to be present when the frontal sinus had mucosal thickening > 3mm involving the entire sinus or dependent portion of the sinus.

Uncinate attachment and its relation to frontal sinus outflow tract

The superior attachment of the uncinate process is an important anatomical structure for the frontal recess region.

Landsberg and Friedman defined two types of FSOT that were medial or lateral to the uncinate process .They also classified superior attachment of uncinate process into 6 types.

Type 1 / 2 : insertion into lamina papyracea

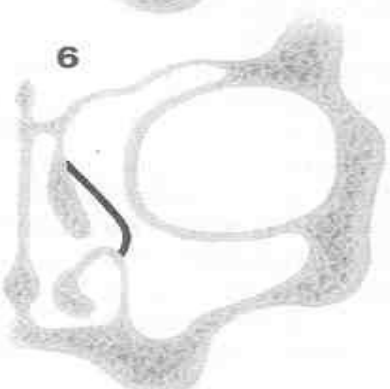
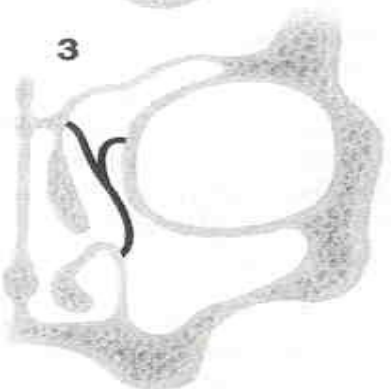
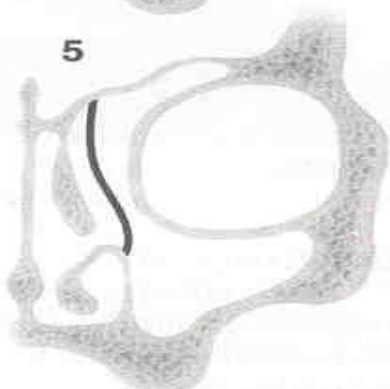
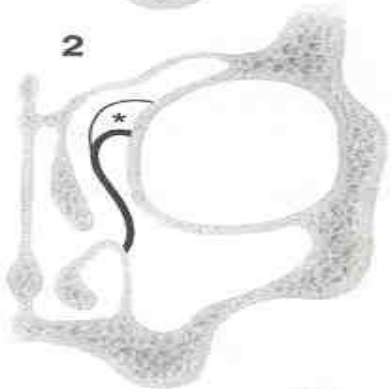
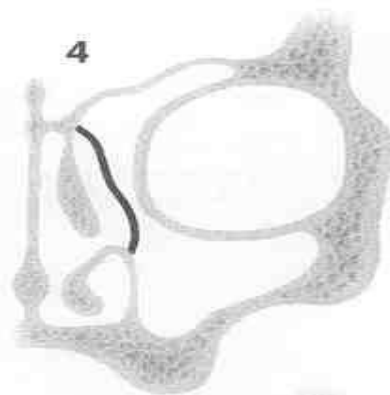
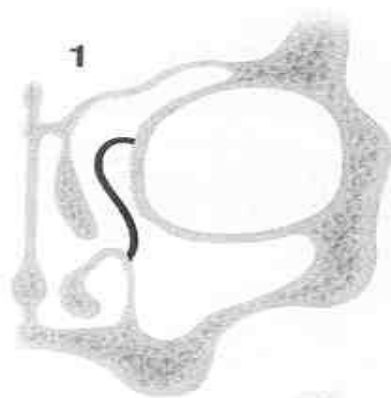
Type 3 : insertion into both lamina papyracea and the junction of the middle turbinate with cribriform plate.

Type 4 : insertion into junction of middle turbinate with cribriform plate

Type 5 : insertion into skull base

Type 6 : insertion into middle turbinate.

Drainage of the frontal sinus to middle meatus (medial to superior attachment of uncinate process [types 1-3]) was classified as group one, and drainage of the frontal sinus to the ethmoid infundibulum (lateral to the superior attachment of uncinate process [type 4 – 6]) was classified as group two. **15 (Fig . 5)**



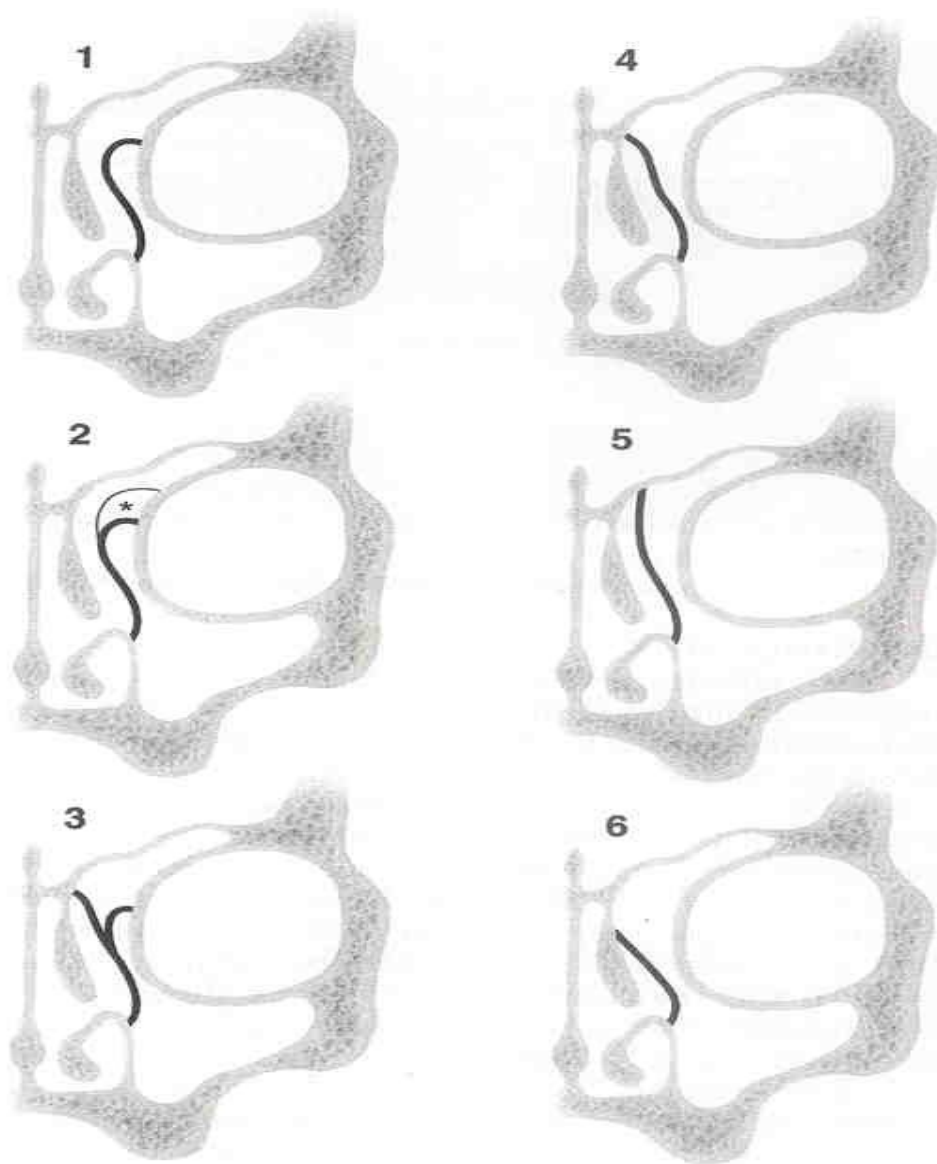


Figure 5 – Types of superior attachment of uncinate process

The relationship between frontal sinusitis and localization of frontal sinus outflow tract

'Turgut et al' evaluated the relationship between frontal sinusitis and the localization of the frontal sinus outflow tract medial or lateral to the superior attachment of uncinate process in 243 patients (486 sides) using CT scans.

They identified the superior attachment of uncinate process in 361 of 486 sides (74 %).

Could not identify attachment in 125 sides (26%).

Of the 361 sides, group 1 drainage (frontal sinus opens medial the uncinate process [types 1-3]) was found in 237 sides (66 %), and group 2 drainage (frontal sinus opens lateral to uncinate process [types 1-3]) was found in 125 sides (35 %).

Insertion of uncinate process into lamina papyracea was the most common type (63%).

Insertion into skull base was second most common(14%).

Of the 361 sides, 125 (35%) were diagnosed as having frontal sinusitis. In cases with group 1 drainage frontal sinusitis was found in 41 %, and in cases with group 2 drainage frontal sinusitis was found in 23%. Compared with cases with group 2 drainage, cases with group 1 drainage had an increased presence of frontal sinusitis that was statistically significant ($p < 0.001$)

The prevalence of superior attachment of uncinate process types was

Type 1/ 2 : 63 %

Type 3 : 3%

Type 4 : 12 %

Type 5 : 14 %

Type 6 : 8 % of cases **16**

Frontal recess air cells: spectrum of CT appearances

'Coates et al' classified the variable patterns of pneumatization of ethmoid bone, cells that extend and enlarge within the ethmoid complex are intramural cells while those cells that extend from the ethmoid complex into adjacent bones are classified as extramural.

Extramural

Agger nasi : these are the most anterior cells of the ethmoid labyrinth that have extended anterior and into the lacrimal bone. On coronal CT, they appear inferior to the frontal recess, lateral to the middle turbinate and lie anterior to the upper end of the nasolacrimal duct. In sagittal plane, they are located anterior and below the frontal recess.

Frontal recess (Kuhn) cells : frontal recess cells are anterior ethmoid air cells that lie posterior to the agger nasi cells and extend anterosuperior to pneumatize the frontal recess.

Supraorbital ethmoid cells : arise from ethmoid group and extends in a superolateral direction between the medial orbital wall and roof of the ethmoid. This results in pneumatization of the orbital plate of the frontal bone posterior to the frontal recess and lateral to the frontal sinus. These may be single or multiple and mimics appearance of septate frontal sinus.

Inferior extensions : air cells may extend into the appendages of the ethmoid bone, that is (1) the middle and superior turbinates; or (2) the uncinate process.

Inferolateral extensions (Haller cells) : air cells that extend into the roof of the maxillary sinus beyond the limits of the ethmoid capsule.

Posterior extensions (Onodi cells) : this is a posterior ethmoid cell that extends posteriorly into the sphenoid bone lying laterally and superior to the sphenoid sinus to abut the optic nerve.

Intramural cells

Cells that extend within the confines of the ethmoid complex to the frontal recess. The ethmoid bulla is an intramural cell that often extends in a posterosuperior direction into the frontal recess forming a frontoethmoid air cell distinct from the frontal recess cells. The bulla usually contains a single air cell but can contain many.

Classification of frontal recess cells

Frontal recess cells are cells that extend from the anterior ethmoid labyrinth into the frontal recess posterosuperior to agger nasi cell. The drainage channel of the frontal recess lies between the anteriorly situated agger nasi and the posterosuperiorly situated frontal recess air cells. Coronal and sagittal CT images clearly show the relationship of these cells to the frontal recess.

Kuhn et al described four types of cells according to appearance on coronal CT scan.

Type 1 – a single cell above the agger nasi cell, which does not pneumatize into the frontal sinus.

Type 2 – a tier of cells above the agger nasi cell, which may or may not pneumatize into the frontal sinus.

Type 3 – a single massive cell above the agger nasi cell, pneumatizing cephalad into the frontal sinus.

Type 4 – single isolated cell within the frontal sinus, frequently difficult to visualize due to its thin walls (sinus within a sinus)

Frontal bullar cell : it is an ethmoid cell above ethmoidal bulla, which pneumatizes along skull base into the frontal sinus, and drains into the frontal recess.

Suprabullar cell : it is an ethmoid cell above ethmoid bulla, which does not extend into the frontal sinus, and drains into the frontal sinus.

Intersinus septal cell : this is a further cell commonly seen in relation to the frontal recess but usually derived from the frontal sinus. They pneumatize the frontal bone between the frontal sinuses and can have mass effect on the frontal recess.

Coates et al concluded that anatomical variants predisposing to paranasal obstruction have been well described in the radiological literature. The frontal cell has not been emphasized as an important potential cause of frontal sinus or frontal recess obstruction, but it should be specifically sought on all routine CT sinus reporting. **17**

Radiological grading system for sinusitis. 18

Task Force on rhinosinusitis recommended staging system for outcomes

research that combines quantification with ease of application. Different staging systems have been described. Lund-Mackay system facilitated the highest level of both interobserver and intraobserver agreement.

1. Lund- Mackay system

<u>Sinus system</u>	Left	Right
Maxillary		
Anterior ethmoid		
Posterior ethmoid		
Sphenoid		
Frontal		
Ostiomeatal complex		

For all sinuses except ostiomeatal complex :

(0 - no abnormality, 1 - partial opacification, 2 – total opacification)

For Ostiomeatal complex (0 - not occluded, 1 - occluded.)

2. Friedman system

- Stage 0 - Normal
- Stage I - Single focus disease (involving a single focus or

single sinus unit)

- Stage II - Multifocal disease (bilateral or multiple areas of

disease that are not confluent or diffuse throughout the ethmoid labyrinth / bilateral middle meatal polyps).

- Stage III - Diffuse disease (extensive bilateral involvement of multiple sinuses) without bony changes.
- Stage IV - Diffuse disease with bony changes.

3. Kennedy system

- Stage 0 Normal
- Stage I - Anatomic abnormalities, all unilateral sinus disease, bilateral disease limited to ethmoidal sinuses.
- Stage II - Bilateral ethmoidal disease with involvement of one dependent sinus.
- Stage III - Bilateral ethmoidal disease with two or more dependent sinuses on each side.
- Stage IV - Diffuse sinonasal polyposis

Levine and May

- Stage 0 - Normal

- Stage I - Disease limited to ostiomeatal complex
- Stage II - Incomplete opacification of one or more sinuses (frontal, maxillary, Sphenoid)
- Stage III - Complete opacification of one or more major sinuses, but not all sinuses.
- Stage IV -Total opacification of all sinuses.

5. **Gliklich and Metson (Harvard system)**

- Stage 0- Normal (< 3mm mucosal thickening on any sinus wall)
- Stage I - all unilateral disease or anatomic abnormality
- Stage II- Bilateral disease limited to ethmoidal or maxillary sinuses
- Stage III - Bilateral disease with involvement of at least one sphenoidal or frontal sinus
- Stage IV - Pansinusitis

MATERIALS AND METHODS

PRESENT STUDY

50 controls and 50 cases were studied from June 2006 to Aug 2007

It was a retrospective and prospective study

Controls and cases were randomly selected

Controls

Were those patients who underwent axial CT scan of temporal bone with 1 mm cuts for non sinus disease (for eg : patients who underwent CT temporal bone for fracture temporal bone, chronic suppurative otitis media) , with absence of significant sinonasal symptoms as established by chart reviews. The analysis was done retrospectively. CT scans of these patients were retrieved from PACS (Picture Archival and Communication System) .

Sagittal , coronal and axial reconstructed 1 mm images of the frontal sinus outflow tract were created using a specific workstation. The scans were then reviewed with the help of Radiologist . The findings were noted, documented and analysed using SPSS (Statistical Package for Social Sciences) software package.

Cases

Those who were clinically diagnosed of Chronic Frontal Rhinosinusitis, based on the inclusion criteria as described below :

Inclusion criteria:

Patients of age between 15- 65 yrs with 12 weeks or more, of signs and symptoms suggestive of frontal rhinosinusitis with

Two major factors or

One major factor and two minor factors

and or nasal purulence on examination.

Major Criteria

1. Facial pain or pressure.
2. Nasal obstruction or blockage.
3. Nasal discharge or purulence or discolored postnasal discharge.
4. Hyposmia or anosmia.

Minor criteria

1. Headache.

2. Fever.
3. Halitosis.
4. Fatigue.
5. Dental pain.
6. Cough.
7. and ear pain, pressure, or fullness.

Exclusion criteria

was patients with :

1. Acute frontal rhinosinusitis.
2. Clinically proven allergy.
3. Nasal mass / malignancies / extensive nasal polyposis.
4. Previous history of sinonasal surgeries.
5. Fungal sinusitis.

METHOD OF COLLECTION OF DATA

Patients were explained about the study and procedures.

Informed consent was taken.

They underwent detailed history and examination followed by diagnostic nasal endoscopy.

Subsequently they underwent Computer Tomography of the paranasal sinuses with 1 mm cuts (axial images). Sagittal and coronal reconstructed 1 mm images of the frontal sinus outflow tract were created using a specific workstation. The scans were then reviewed with the help of Radiologist. The findings were noted , documented, and analyzed using SPSS software package.

RESULTS

The following are the results of MULTIPLANAR COMPUTER TOMOGRAPHY scans of 50 controls and 50 cases.

Statistical significance was obtained using Chi-square test
($p < 0.05$ was significant)

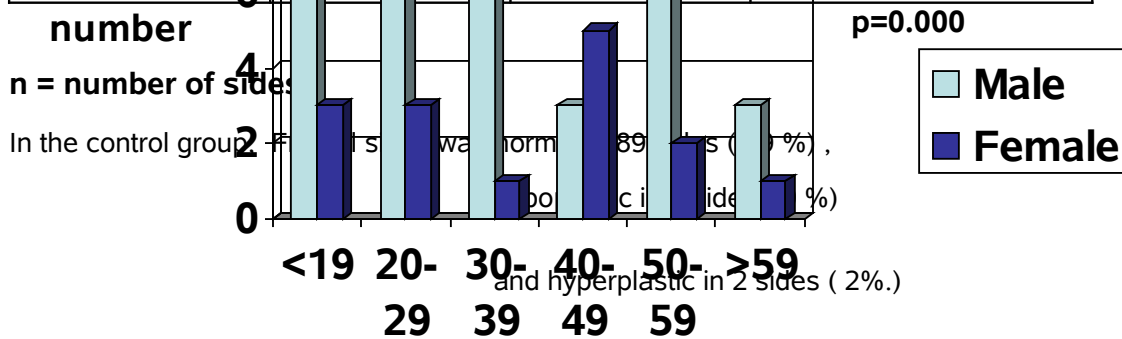
AGE, SEX DISTRIBUTION

Controls and cases were selected between 15 to 65 years of age. (Fig. 6)

Figure 6 – Age sex distribution

Table – I FRONTAL SINUS

Frontal sinus Appearance	Controls n (%)	Cases n (%)	Total
Normal	89 (89)	75 (75)	164
Hypoplastic	9 (9)	2 (2)	11
Hyperplastic	2 (2)	23 (23)	25
Total	100	100	200



In the case group, frontal sinus was normal in 75 (75 %) ,

hypoplastic in 2 sides (2%) and

hyperplastic in 23 sides (23 %).

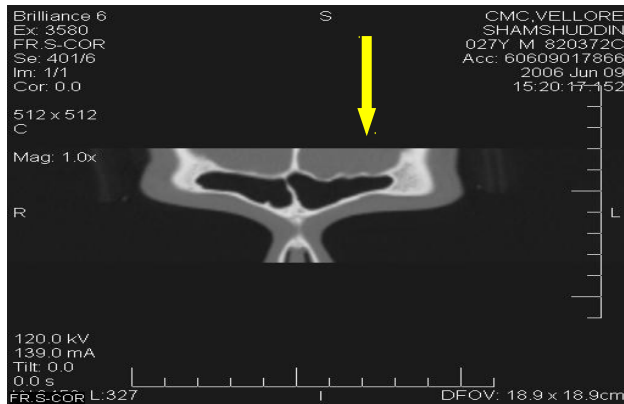


Figure 7 – Normal frontal sinus, coronal section

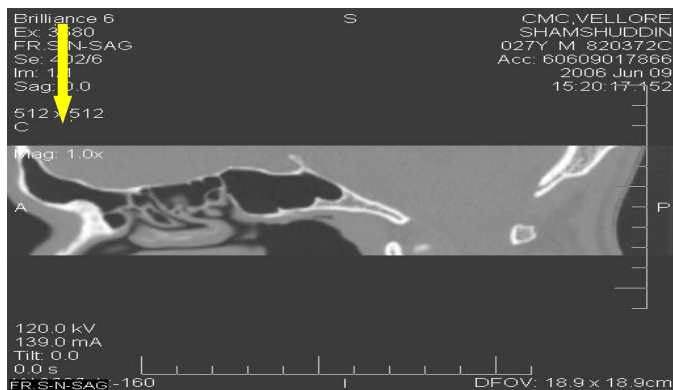


Figure 8 - Normal frontal sinus, sagittal section

Figure 9 - Normal frontal sinus, axial section



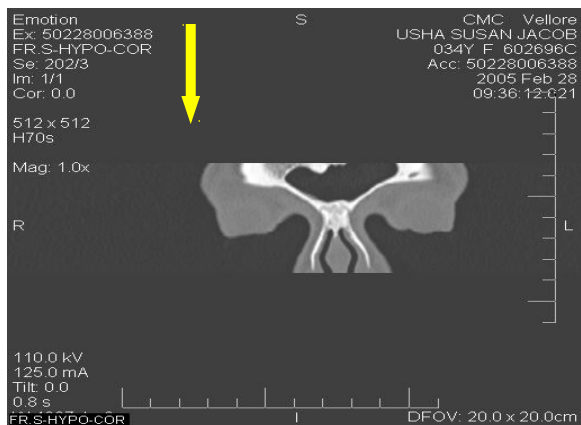


Figure 10 – Hypoplastic frontal sinus, coronal section

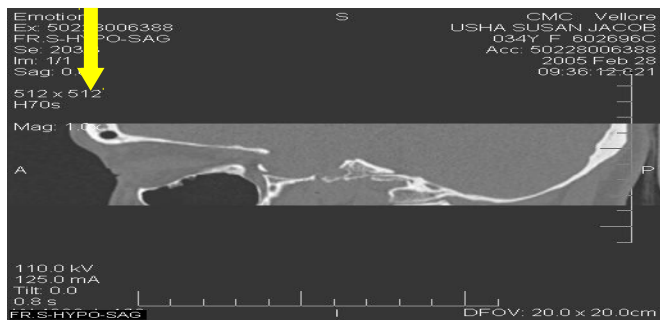


Figure 11 – Hypoplastic frontal sinus, sagittal section

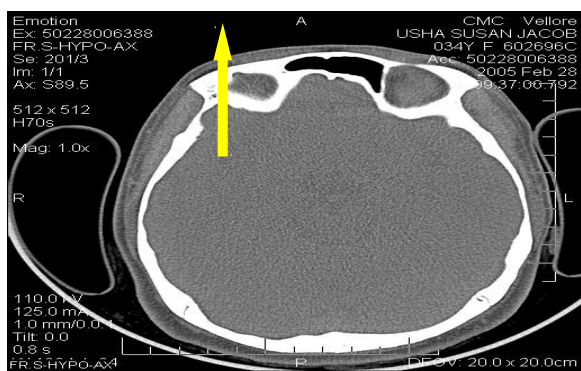


Figure 12 – Hypoplastic frontal sinus, axial section

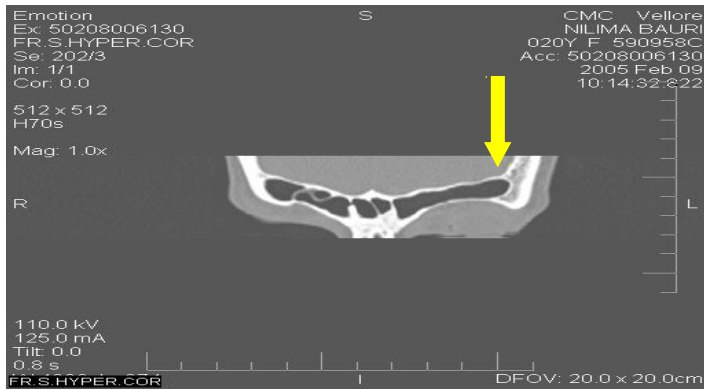


Figure 13 – Hyperplastic frontal sinus, coronal section

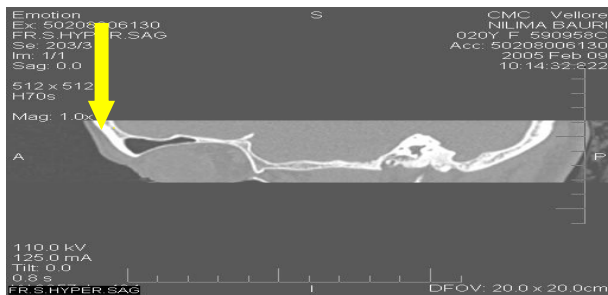


Figure 14 – Hyperplastic frontal sinus, sagittal section

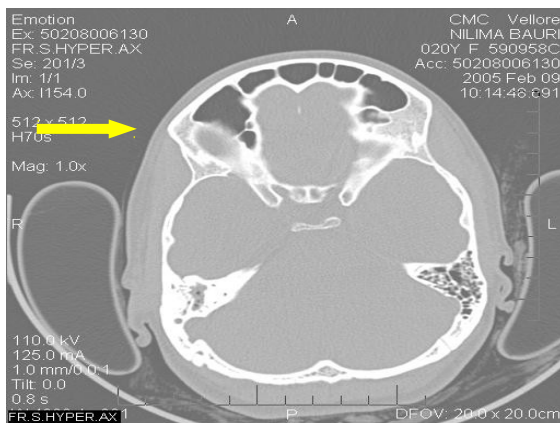


Figure 15 – Hyperplastic frontal sinus, axial section

Table – II AGGER NASI CELLS

Agger nasi cell	Controls n (%)	Cases n (%)	Total
Present	94 (94 %)	100 (100 %)	194
Absent	6 (6 %)	0 (0 %)	6
Total	100	100	200

p=0.029

In the control group agger nasi cells were present in 94 sides (94 %)

and absent in 6 sides (6 %).

In the case group agger nasi cells were present in all the sides (100%)

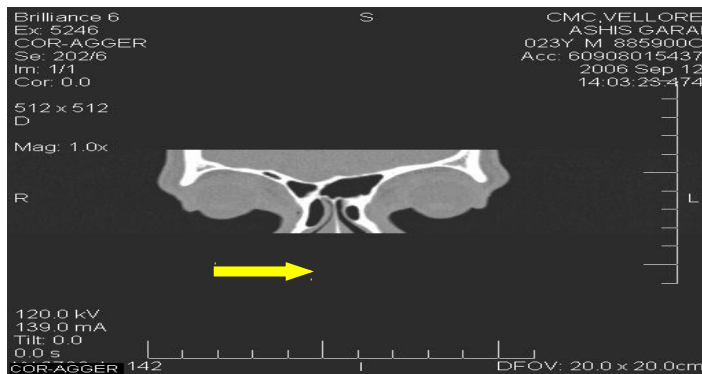


Figure 16 – Agger nasi cell , coronal section

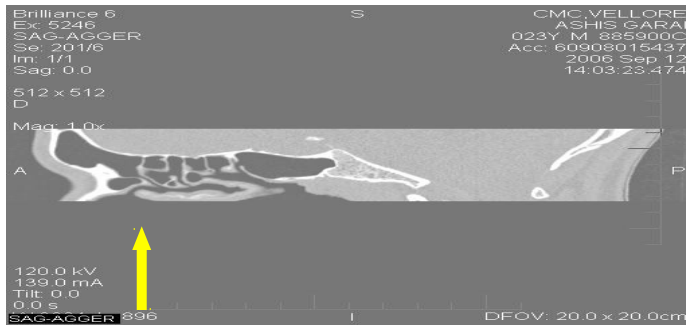


Figure 17 – Agger nasi cell , sagittal section

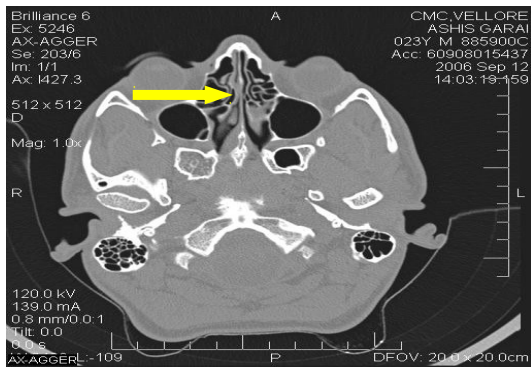


Figure 18 – Agger nasi cell , axial section

Table – III FRONTAL CELLS

Frontal cells	Controls n (%)	Cases n (%)	Total
Present	44 (44%)	60 (60 %)	104
Absent	56 (56 %)	40 (40 %)	96
Total	100	100	200

p = 0.024

In the control group frontal cells were present in 44 sides (44%),

and absent in 56 sides (56%)

In the case group frontal cells were present in 60 sides (60%),

and absent in 40 sides (40%)

Table – IV TYPE OF FRONTAL CELLS

Type of frontal cell	Controls n (%)	Cases n (%)	Total
Type 1	24 (24%)	23 (%)	47
Type 2	10 (10 %)	9 (9 %)	19
Type 3	10 (10 %)	28 (28 %)	38
Total	44	60	104

p = 0.010

In the control group type 1 cells were found in 24sides (24%),

type 2 cells were found in 10 sides (10%) ,

type 3 cells were found in 10 sides (10 %),

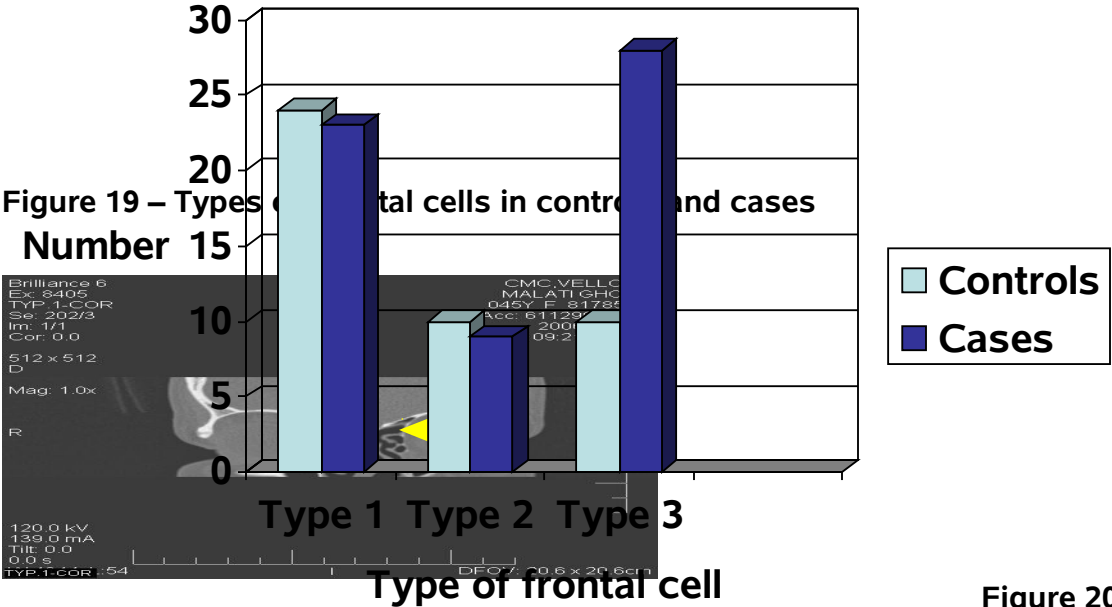
type 4 cells were 0 %.

In the case group type 1 cells were found in 23 sides (23%),

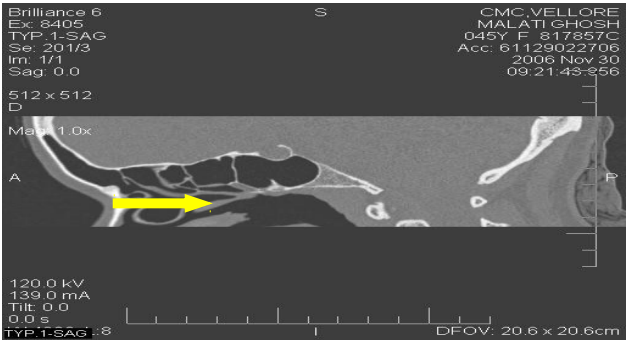
type 2 cells were found in 9 sides (9%),

type 3 cells were found in 28 sides (28%)

type 4 cells were 0%.



Type 1 frontal cell , coronal section



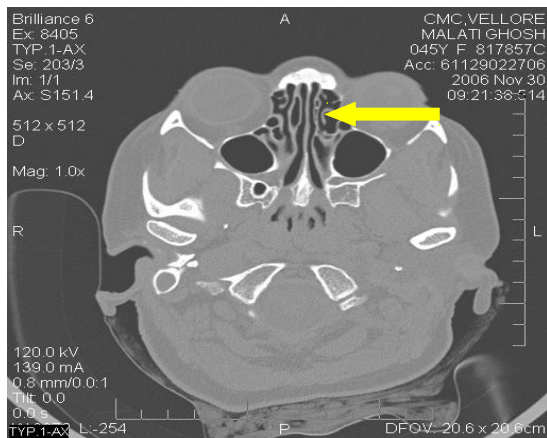


Figure 22 – Type 1 frontal cell , axial section

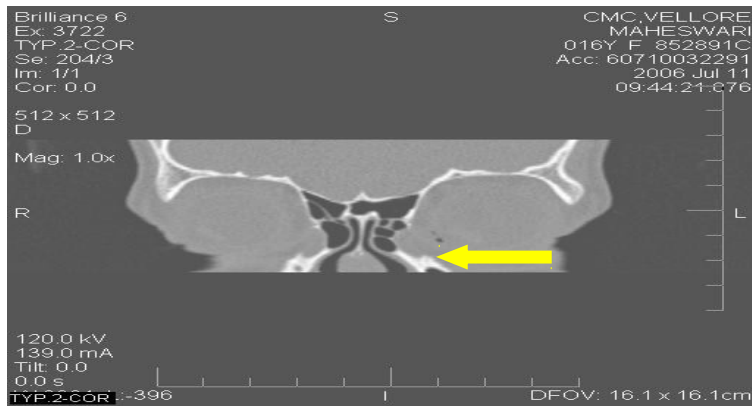


Figure 23 – Type 2 frontal cell , coronal section

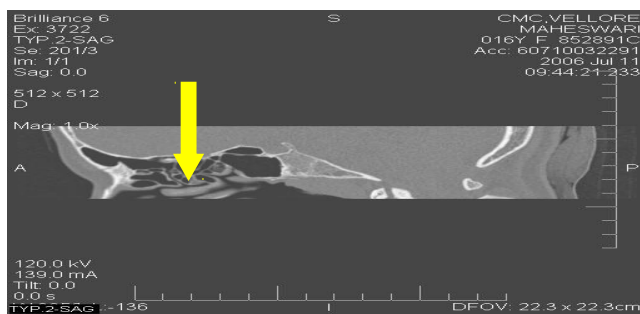


Figure 24 – Type 2 frontal cell , sagittal section

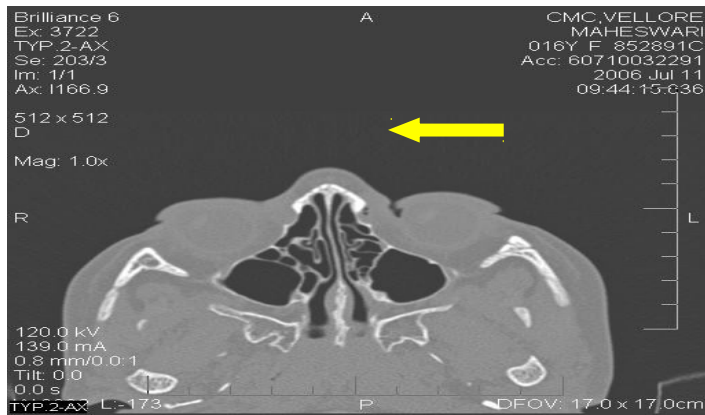


Figure 25 – Type 2 frontal cell , axial section

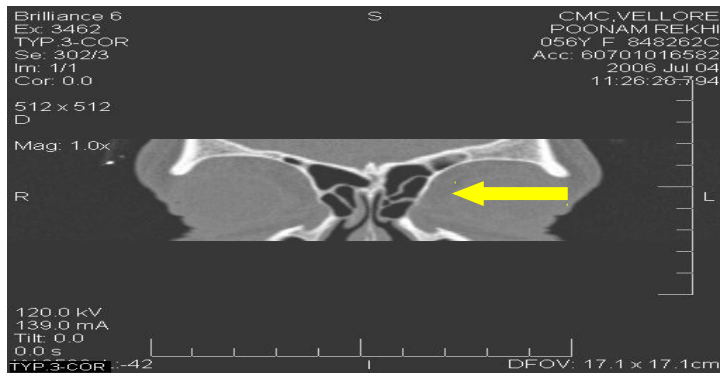


Figure 26 – Type 3 frontal cell , coronal section

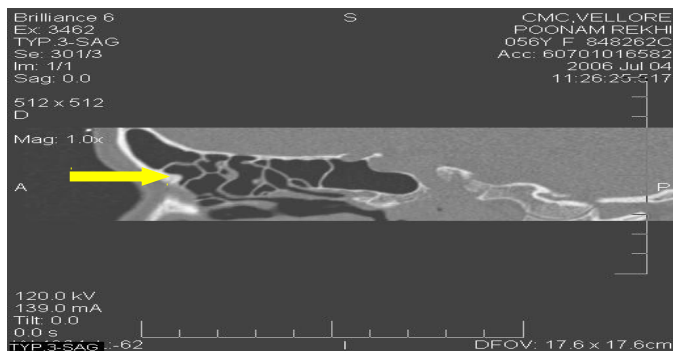


Figure 27 – Type 3 frontal cell , sagittal section

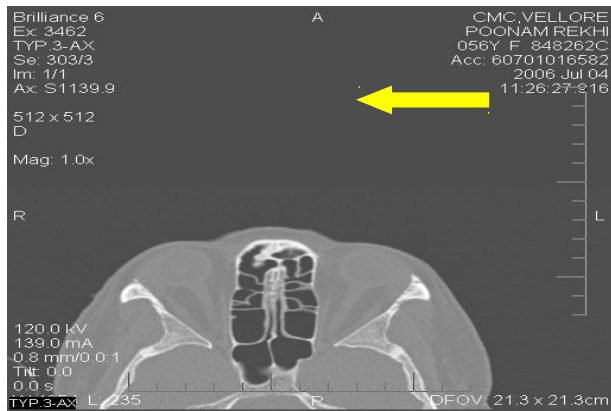


Figure 28 – Type 3 frontal cell , axial section

Table – V FRONTAL BULLAR CELLS

Frontal Bullar cells	Controls n (%)	Cases n (%)	Total
Present	14 (14 %)	26 (26 %)	40
Absent	86 (86 %)	74 (74 %)	160
Total	100	100	200

$$p = 0.034$$

Frontal bullar cells were present in 14 sides (14%) in control group,

and in 26 sides (26%) in case group

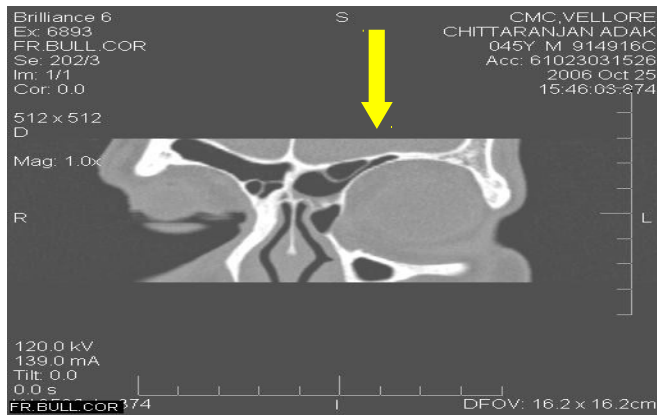


Figure 29 – Frontal bullar cell , coronal section

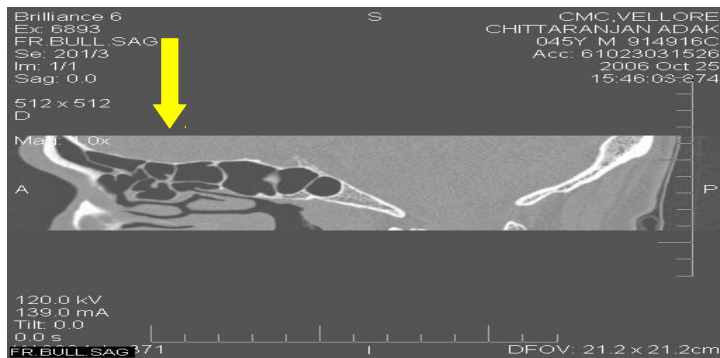


Figure 30 – Frontal bullar cell , sagittal section

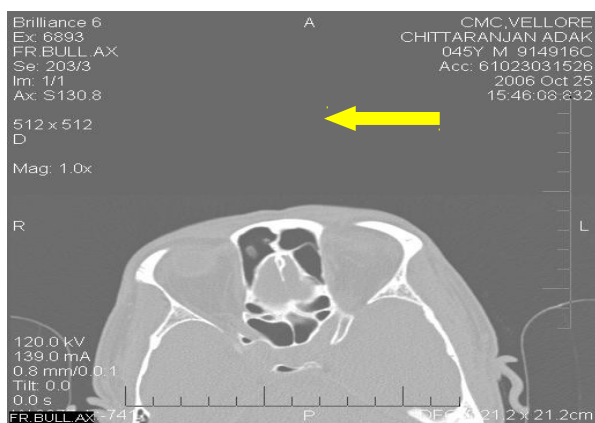


Figure 31 – Frontal bullar cell , axial section

Table - VI SUPRABULLAR CELLS

Suprabullar cells	Controls n (%)	Cases n (%)	Total
Present	13 (13 %)	19 (19 %)	32
Absent	87 (87 %)	81 (81 %)	168
Total	100	100	200

$$p = 0.247$$

Suprabullar cells were present in 13 sides (13%) in control group,

and in 19 sides (19%) in case group.

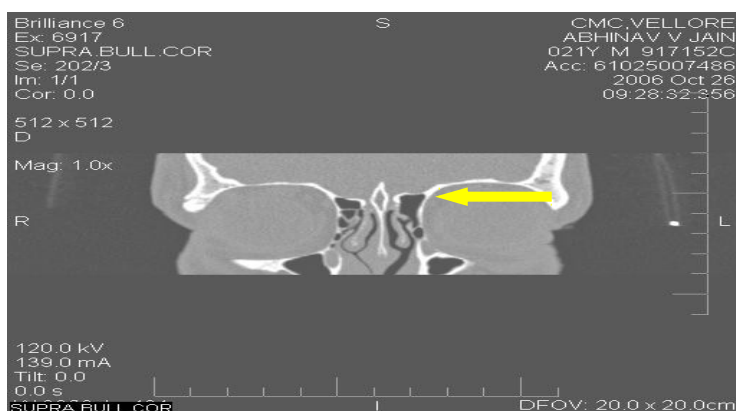


Figure 32 – Suprabullar cell , coronal section

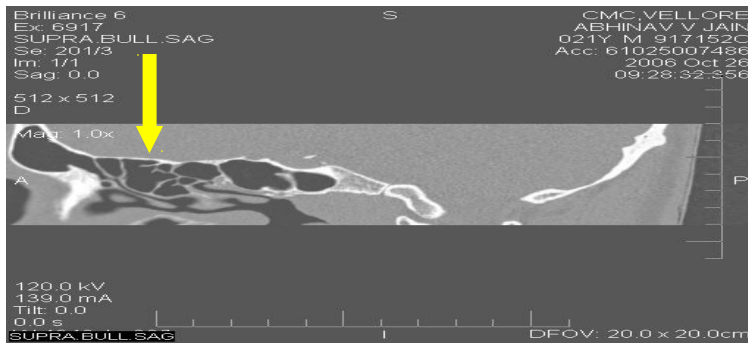


Figure 33 – Suprabullar cell , sagittal section

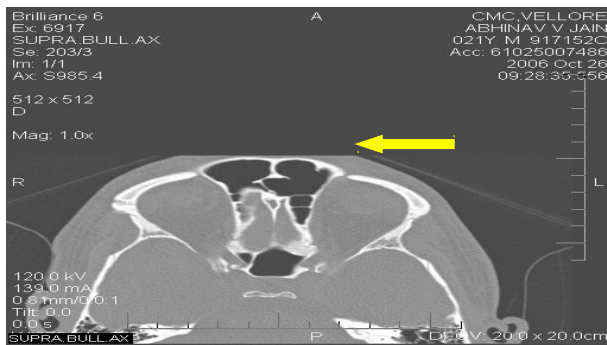


Figure 34 – Suprabullar cell , axial section

Table - VII SUPRAORBITALETHMOIDALCELLS

Supraorbitalethmoidal cells	Controls n (%)	Cases n (%)	Total
Present	22 (22 %)	25 (25 %)	47
Absent	78 (78 %)	75 (75 %)	153
Total	100	100	200

p = 0.617

Supraorbital ethmoidal cells were present in 22 sides (22%) in control group,
and in 25 sides (25%) in case group.

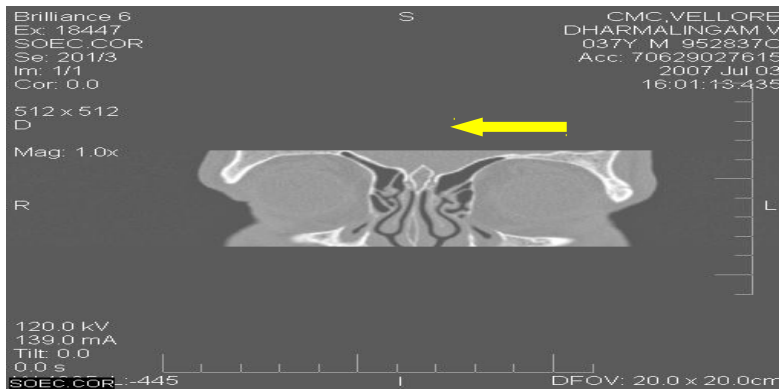


Figure 35 – Supraorbital ethmoidal cell , coronal section

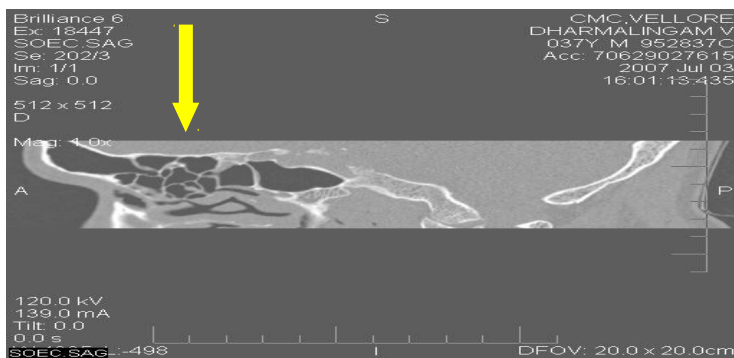


Figure 36 – Supraorbital ethmoidal cell , sagittal section

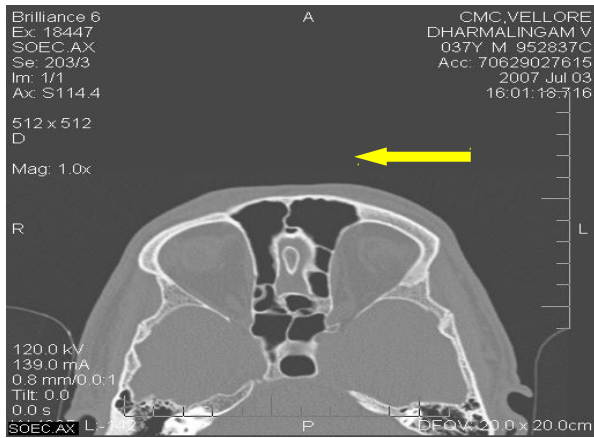


Figure 37 – Supraorbital ethmoidal cell , axial section

Table - VIII INTERFRONTAL CELLS

Interfrontal cells	Controls n (%)	Cases n (%)	Total
Present	5 (5 %)	20 (20 %)	25
Absent	45 (45 %)	30 (20 %)	75
Total	50	50	100

p = 0.001

Inter frontal cells were present in 5 sides (5%) in control group,

and in 20 sides (20%) in case group.

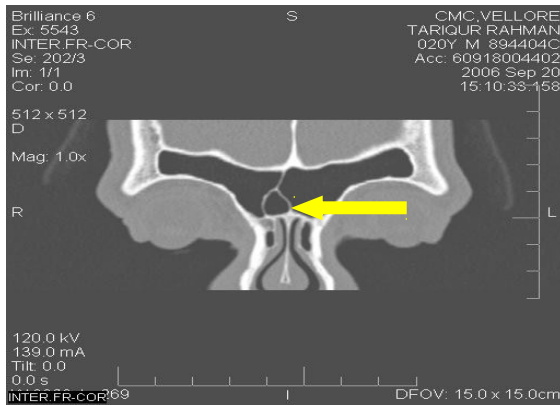


Figure 38 – Interfrontal septal cell , coronal section

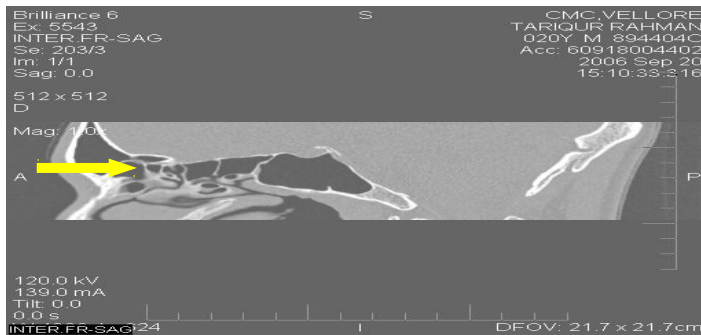


Figure 39 – Interfrontal septal cell , sagittal section

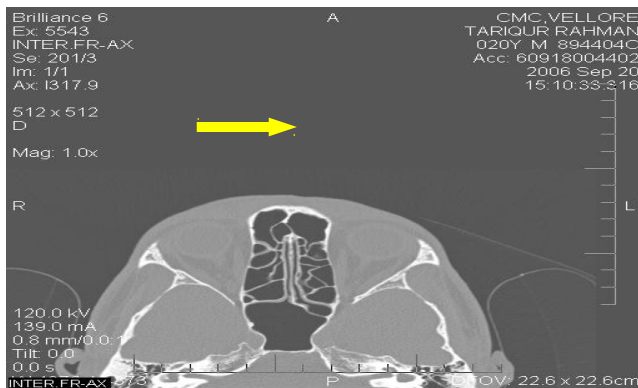


Figure 40 – Interfrontal septal cell , axial section

Table IX - NASAL SEPTUM

Nasal septum	Controls n (%)	Cases n (%)	Total
Deviated	22 (22%)	32 (32 %)	54
Not deviated	28 (28%)	18 (18%)	46
Total	50	50	100

p = 0.045

Nasal septum was deviated in 22 sides (22%) in the control group,

and in 32 sides (32%), in the case group.

Table – X SUPERIOR ATTACHMENT OF UNCINATE PROCESS

Types of uncinate attachment	Controls n (%)	Cases n (%)	Total
Type 1, 2	61 (61 %)	83 (83 %)	144
Type 3	34 (34 %)	11 (11 %)	45
Type 4	2 (2 %)	0 (0 %)	2
Type 5	1 (1 %)	0 (0 %)	1
Type 6	2 (2 %)	6 (6 %)	8
Total	100	100	200

p = 0.000

The superior attachment of uncinate process was found to be as follows-

In the control group : Type 1,2 – 61 sides (61 %)

Type 3 – 34 sides (34%)

Type 4 – 2 sides (2%)

Type 5 – 1 side (1%)

Type 6 – 2 sides (2%)

In the case group : Type 1 , 2 - 83 sides (83 %)

Type 3 – 11 sides (11%)

Type 6 - 6 sides (6%)

Table - XI DIAMETER AND AREA OF NASOFRONTAL ISTHMUS

Measurement	Group	Mean	Standard deviation
Anteroposterior diameter (mm)	Controls	1.447	0.5394
	Cases	1.689	0.8055
Transverse diameter (mm)	Controls	1.254	0.5128
	Cases	1.372	0.8149
Area (mm²)	Controls	1.9527	1.63733
	Cases	2.4120	2.30496

Anteroposterior diameter : **p = 0.013**

Transverse diameter : **p = 0.222**

Area of isthmus : $p = 0.106$

The above table shows the anteroposterior diameter, tranverse diameter and area of isthmus

in controls (group 1) and cases (group 2)

In the case group two additional parameters were studied.

The frontal recess and the grade of frontal sinus disease.

Table – XII FRONTAL RECESS

Frontal Recess	Sides - n (%)
Normal	61 (61 %)
Obstructed	39 (39 %)
Total	100

In the case group 61 sides (61%) were normal , and 39 sides (39%) were obstructed.

Table – XIII FRONTAL SINUS DISEASE GRADING

Frontal sinus disease grading	Sides - n (%)
Grade 0	75 (75 %)
Grade 1	2 (%)
Grade 2	23 (23 %)
Total	100

In the case group 75 sides (75%) had grade 0 disease, 2 sides (2%) had grade 1 disease,

23 sides (23%) had grade 2 disease.

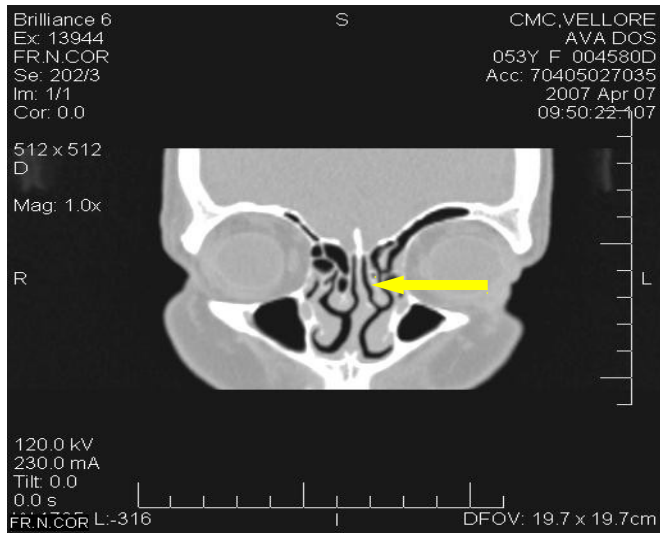


Figure 41 – Normal frontal recess , coronal section

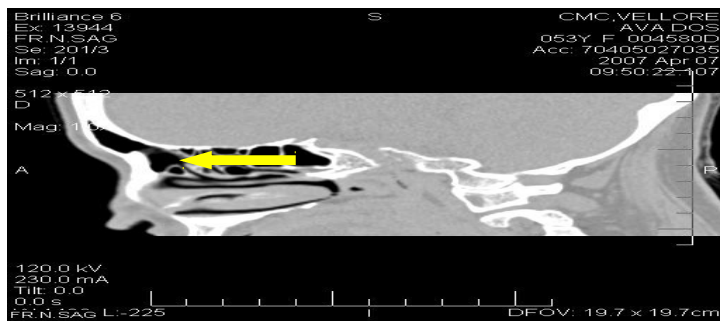


Figure 42 – Normal frontal recess , sagittal section

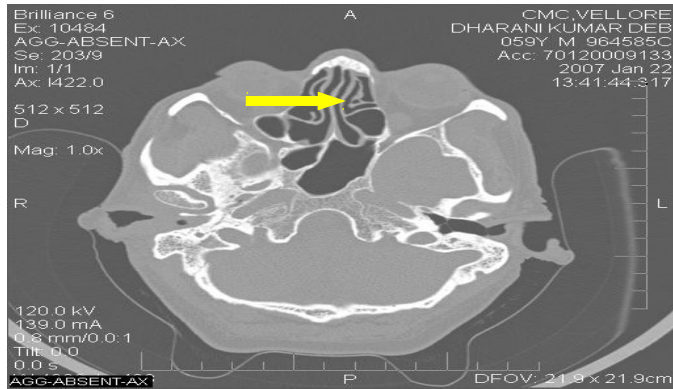


Figure 43 – Normal frontal recess , axial section



Figure 44 – Obstructed frontal recess , coronal section

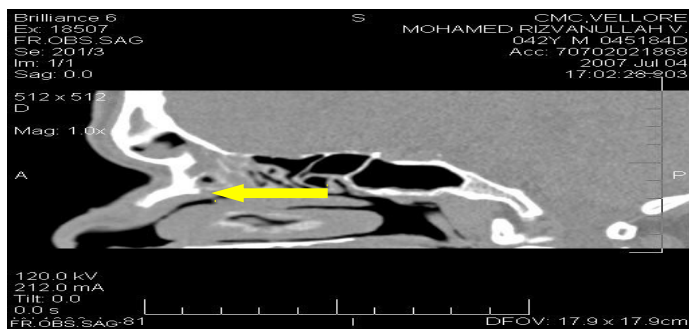


Figure 45 – Obstructed frontal recess , sagittal section

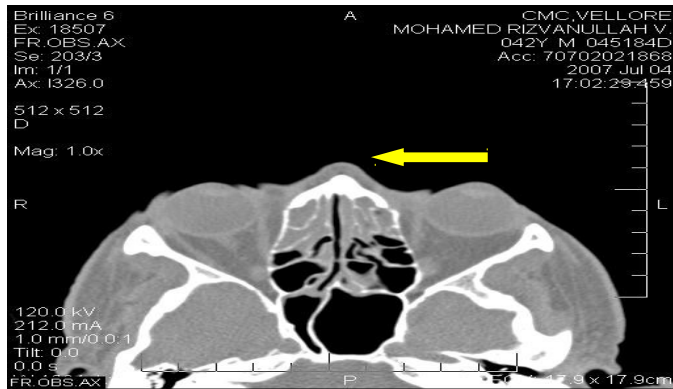


Figure 46 – Obstructed frontal recess , axial section

Table – XIII FRONTAL SINUS DISEASE GRADING

Frontal sinus disease grading	Sides - n (%)
Grade 0	75 (75 %)
Grade 1	2 (%)
Grade 2	23 (23 %)
Total	100

In the case group 75 sides (75%) had grade 0 disease, 2 sides (2%) had grade 1 disease, 23 sides (23%) had grade 2 disease.

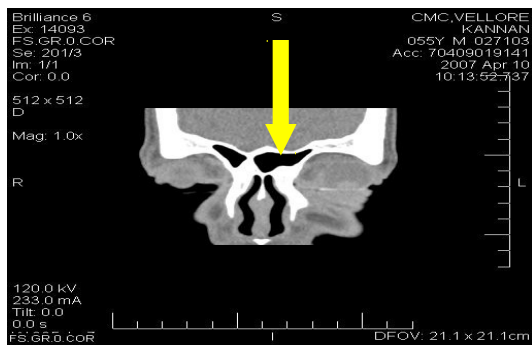


Figure 47 - Frontal sinus disease : grade 0, coronal section

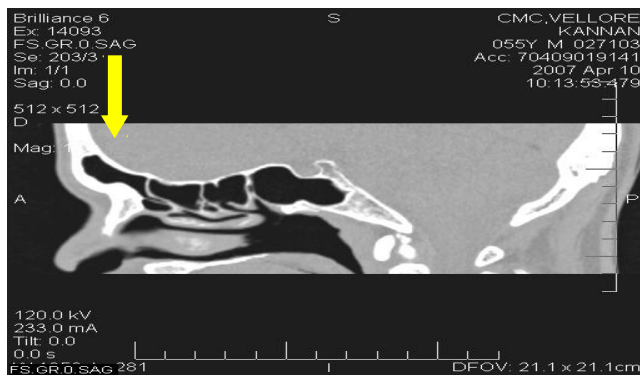


Figure 48 - Frontal sinus disease : grade 0 , sagittal section

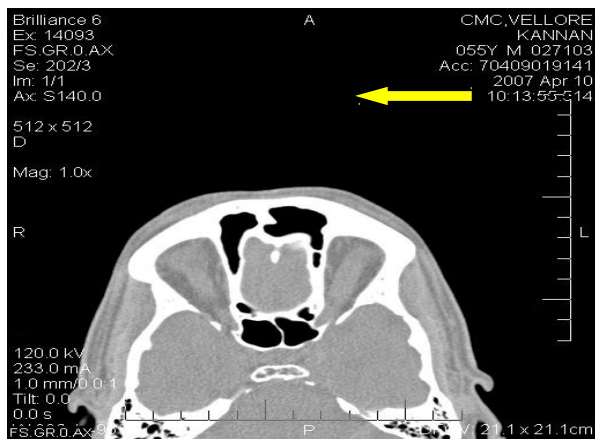


Figure 49 - Frontal sinus disease : grade 0 , axial section

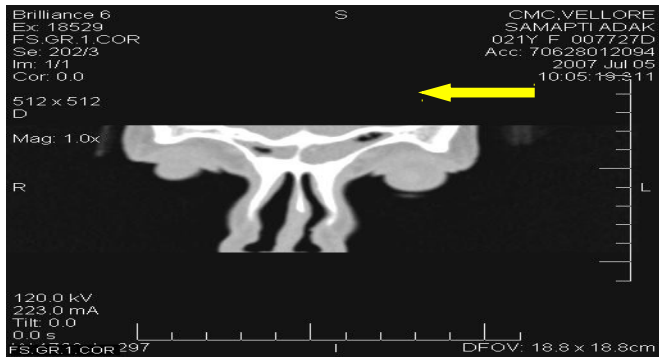


Figure 50 - Frontal sinus disease : grade 1 , coronal section

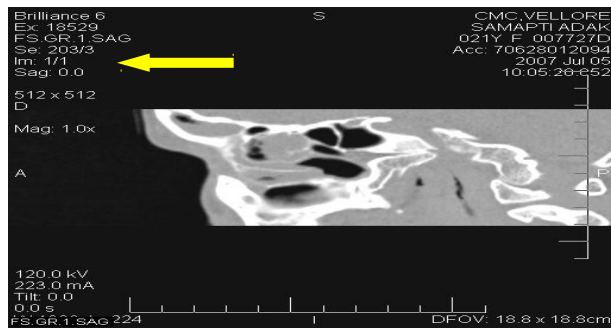


Figure 51 - Frontal sinus disease : grade 1 , sagittal section

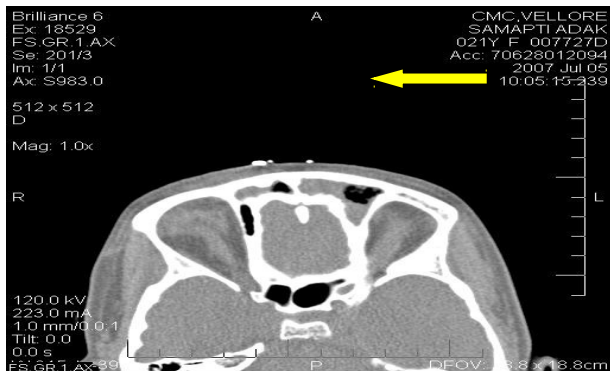


Figure 52 - Frontal sinus disease : grade 1 , axial section

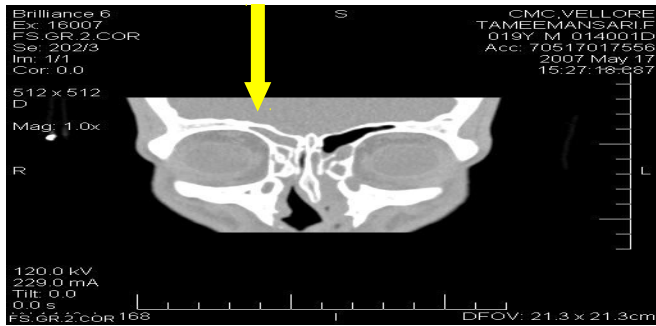


Figure 53 - Frontal sinus disease : grade 2 , coronal section

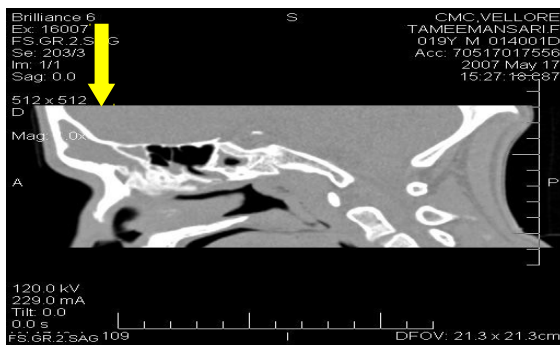


Figure 54 - Frontal sinus disease : grade 2 , sagittal section

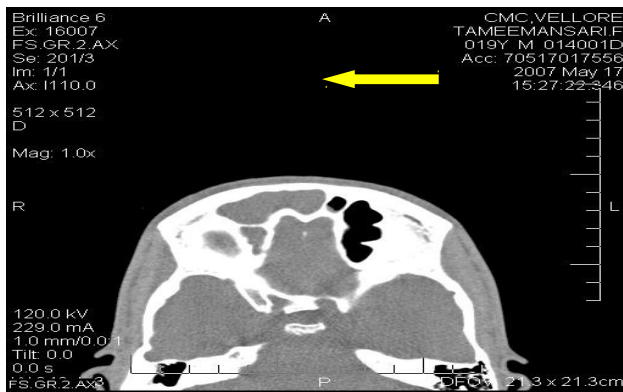


Figure 55 - Frontal sinus disease : grade 2 , axial section

DISCUSSION

Frontal sinus pneumatization

Multiplanar computed tomographic analysis of frontal sinus outflow tract in previous studies have been done in patients with no sinusitis or in patients with chronic sinusitis.

'Meyer et al' determined the prevalence of frontal cells and other anatomic variants and examined their relationships in a study of 768 coronal CT scans. **9**

'Kew et al' assessed the use of multiplanar reconstructed computed tomography images of frontal recess and sinuses with regard to depiction and understanding the anatomy and effect on surgical approach in 43 patients. **10**

'Walter T Lee et al' described frontal sinus pneumatization in 50 patients with no history of frontal sinus disease using 3 dimensional computed tomography. **11**

'DelGaudio et al' determined the prevalence of frontal recess cells and their relationship to frontal sinusitis using multiplanar reconstructed CT images in 106 patients. **13**

There has been no comparative study of frontal sinus outflow tract in patients without sinusitis and in patients with sinusitis.

In this series frontal sinus outflow tract has been studied in 50 patients without sinusitis and in 50 patients with sinusitis, and compared using multiplanar computed tomography.

The frontal sinus was found to be abnormal in significantly higher number of patients in the case group (i.e. hypoplastic or hyperplastic) (p = 0.000)

Agger nasi cells

‘Walter T Lee et al’ reported the prevalence of agger nasi cell to be 89% in 50 patients without sinusitis. **11**

‘Meyer et al’ showed that agger nasi cell was present in 86.7 % of patients with sinusitis. **9**

Van Alyea reported it in 89 % of patients, recently Bolger et al reported it in 98.5 % of patients.

In this series agger nasi cell was found in 94% of controls and 100% of cases

(p = 0.029)

Frontal cells

‘Meyer et al’ reported the prevalence of frontal cells to be 20.4% in 768 coronal CT scans . **9**

‘DelGaudio et al’ reported a 33% prevalence of frontal cells using multiplanar reconstructed CT images in 106 patients. **13**

'Van Alyea' found a 40 % incidence of frontal cells. **14**

'Kew et al' assessed the use of multiplanar reconstructed computed tomography images of frontal recess in 43 patients and found that there was no statistically significant difference between the Bent and Kuhn classification of frontoethmoidal cells on coronal and parasagittal images

($p > 0.05$) .**10**

In this series frontal cells were found in 44% of controls and 60% of cases ($p = 0.024$)

Types of frontal cell

'Meyer et al' reported the prevalence of frontal cells on coronal scans as :

Type 1 cells - 14.9 %

Type 2 cells - 1.7 % and

Type 4 cells - 3.1 % .**9**

'Walter T Lee et al' reported the prevalence of frontal cells on 3D computer scans as:

Type 1 frontal cells : 37 %

Type 2 frontal cells : 19 %

Type 3 frontal cells : 8 %

Type 4 frontal cells : 0 % . **11**

'DelGaudio et al' reported the prevalence of frontal cells on multiplanar computed tomography

as

Type 1 cells being most common (18.4 %)

Type 2 cells in 2 % of cases

Type 3 cells in 6.1 % of cases

Type 4 cells in 3.1 % of cases. **13**

In this series prevalence of frontal cells were as follows :

in control group :

Type 1 cells : 24 %

Type 2 cells : 10 %

Type 3 cells : 10 %

Type 4 cells : 0 %

and in case group :

Type 1 cells : 23 %

Type 2 cells : 9 %

Type 3 cells : 28 %

Type 4 cells : 0 % ($p = 0.010$)

Frontal bullar cells, suprabullar cells, supraorbital ethmoidal cells and interfrontal septal cells

‘Walter T Lee et al’ reported the prevalence of frontal bullar cells, suprabullar cells, supraorbital ethmoidal cells and interfrontal septal cells using 3 dimensional computer tomography as follows :

Frontal bullar cell : 9 %

Suprabullar cell : 15 %

Supraorbital ethmoidal cell : 62 %

Interfrontal sinus septal cell : 14 % .**11**

‘DelGaudio et al’ reported the prevalence Interfrontal septal cells on multiplanar computed tomography as 12.2 % .**13**

In this series

Frontal bullar cells were found in 14% in control group, and in 26% in case group.

($p = 0.034$)

Suprabullar cells were found in 13% in control group, and in 19 % in case group.

($p = 0.247$)

Supraorbital ethmoidal cells were found in 22% in control group, and in 25 % in case group.

($p = 0.617$)

Interfrontal septal cells were found in 5% in control group, and in 20% in case group

($p = 0.001$)

Nasal septum

Nasal septum was deviated in 22 sides (22%) in the control group,

and in 32 sides (32%), in the case group ($p = 0.045$)

Superior attachment of uncinate process

'Turgut et al' reported the prevalence of superior attachment of uncinate process in 361 sides
as follows :

Type 1/ 2 : 63 %

Type 3 : 3%

Type 4 : 12 %

Type 5 : 14 %

Type 6 : 8 % of cases **16**

**In this series superior attachment of uncinate process was found to be as
follows**

In control group :

Type 1, 2 : 61%

Type 3 : 34 %

Type 4 : 2%

Type 5 : 1%

Type 6 : 2%

In case group :

Type 1, 2 : 83%

Type 3 : 11 %

Type 6 : 6% **(p = 0.000)**

Diameter and area of nasofrontal isthmus

The mean anteroposterior diameter of nasofrontal isthmus was 1.447 in control group, and 1.689 in case group, (p = 0.013)

The mean transverse diameter of nasofrontal isthmus was 1.254 in control group, and 1.372 in case group. (p = 0.222)

The mean area of nasofrontal isthmus was 1.9527 in control group, and 2.4120 in case group. (p = 0.106)

Frontal recess

In the case group frontal recess was normal in 61 sides (61 %), and obstructed in 39 sides (39 %) .

Frontal sinus disease grading

In the case group frontal sinus disease was grade 0 in 75 sides (75%) , grade 1 in 2 sides (2%) , and grade 2 in 23 sides (23%) .

CONCLUSION

This study concludes that multiplanar computer tomography of the paranasal sinuses greatly improves our understanding of the frontal sinus outflow tract.

Simultaneous review of the triplanar images at the computer workstation facilitated the description of frontal sinus and frontal recess pneumatization patterns.

Thus prevalences of specific pneumatization patterns could be studied in patients with normal healthy frontal sinuses, and in patients with chronic rhinosinusitis.

The frontal sinus was found to be abnormal in higher number of patients in the case group (i.e. hypoplastic or hyperplastic).

Agger nasi cells were almost universal in control group, and universally present in case group.

Type 1 and type 2 frontal cells were almost equally present in control group and in case group, whereas type 3 frontal cells were significantly higher in number in case group.

Type 4 cells were not found in control group or in case group.

Frontal bullar cells and interfrontal septal cells were also significantly higher in case group compared to control group.

There was no significant difference between control group and case group with reference to suprabullar cells and supraorbital ethmoidal cells, though the prevalence was found to be higher in case group.

The nasal septum was deviated in a significant number of patients in case group compared to control group.

Superior attachment of uncinate process was type 1 / 2 in majority of patients both in control group and in case group.

There was a significant difference in anteroposterior diameter of nasofrontal isthmus between the control and case group, however there was no significant difference in transverse diameter and area of nasofrontal isthmus between the two groups.

The frontal recess with regard to obstruction, and frontal sinus disease was not compared because the controls were those without sinusitis.

To summarize the Utility of multiplanar computer tomography images

- Sagittal images were necessary to differentiate between type 1 and type 3 frontal cells.
- Pneumatization of frontal bullar cells and suprabullar cells, was also characterized by sagittal images alone.
- Characterization of supraorbital ethmoidal cells was possible with sagittal and axial images.
- Interfrontal cells were better characterized on axial and coronal images.
- Measurement of anteroposterior and transverse diameter, and area of nasofrontal isthmus was possible with sagittal and coronal images.
- These multiplanar images provided a platform for the preoperative characterization of frontal sinus and recess anatomy.

- Sagittal reconstructed images helped in better understanding and delineation of frontal and accessory cells.
- The three-dimensional understanding of the frontal recess was greatly improved by using coronal, axial, and sagittal reconstructed images as compared to coronal images alone.
-

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APPENDIX - PROFORMA

CASE GROUP

Utility of Multiplanar reconstructed (Sagittally reformatted) CT in the evaluation of

Frontal sinus outflow tract (FSOT)

Serial No:

Name:

Age:

Sex:

Hospital No:

Address:

Clinical Symptoms and Signs:

MAJOR CRITERIA	RIGHT	LEFT
Headache (0,1,2,3)		
Nasal discharge (0,1,2,3)		
Nasal obstruction (0,1,2,3)		
Facial pressure/pain (0,1,2,3)		
(0- none, 1- mild, 2- moderate, 3- severe)		
Postnasal drip (A- present, B- absent)		
Impaired smell (0- no, 1-mild, 2- moderate, 3- severe)		
MINOR CRITERIA		
Sneezing (0- no, 1- <6, 2- 6-12, 3- >12)		
Fever (A- present, B- absent)		
Halitosis (A- present, B- absent)		
Cough (A- present, B- absent)		
Dental Pain (A- present, B- absent)		
Fatigue (A- present, B- absent)		

Otalgia/aural fulness (A- present, B- absent)		
SIGNS		
DNS (0- none, 1- mild, 2- moderate, 3- severe)		
Inferior turbinate (0- N, 1- mild hypertrophy, 2- Moderate, 3- severe)		
Middle turbinate (0- normal, 1- hypertrophied)		
Nasal discharge (0- nil, 1- mucoid, 2- purulent, 3- crusty)		
Mucosa (0- normal , 1- congested, 2- edematous, 3- polypoid)		
Post nasal discharge (0- nil, 1- mucoid, 2- purulent, 3- crusty)		

H/O Nasal allergies----yes/no if yes, specify:

H/O Drug usage/topical nasal- yes/no if yes, specify:

H/O Systemic disease- yes/no if yes, specify:

Coronal CT scan PNS- FSOT

	RIGHT	LEFT
Frontal sinus (0-normal, 1- hypoplastic, 2- hyperplastic)		
Frontal recess (0- normal, 1- Obstructed)		
Frontal sinus disease (LM grading 0,1,2)		
Agger nasi cell (0- absent, 1- present)		
Frontal cells (0- absent, 1- present)		
Frontal cells (1- type 1, 2- type 2, 3-type3, 4-type 4)		
Supraorbital ethmoid cell (0- absent, 1- present)		
Interfrontal sinus cell septal cell (0- absent, 1- present)		
Uncinate attachment (types 1,2,3,4,5,6)		

Multiplanar CT scan PNS-FSOT

	RIGHT	LEFT
Frontal sinus (0-normal, 1- hypoplastic, 2- hyperplastic)		
Frontal recess (0- normal, 1- Obstructed)		
Frontal sinus disease (LM grading 0,1,2)		
Agger nasi cell (0- absent, 1- present)		
Frontal cells (0- absent, 1- present)		
Frontal cells (1- type 1, 2- type 2, 3 - type3, 4-type 4)		
Frontal bullar cell (0- absent, 1- present)		
Suprabullar cell (0- absent, 1- present)		
Supraorbital ethmoid cell (0- absent, 1- present)		
Interfrontal sinus cell septal cell (0- absent, 1- present)		
Uncinate attachment (types 1,2,3,4,5,6)		
Anteroposterior diameter of Nasofrontal isthmus in mm		
Transverse diameter		
Area of nasofrontal isthmus (mm ²)		

PROFORMA - CONTROL GROUP

Utility of Multiplanar reconstructed (Sagittally reformatted) CT in the evaluation of Frontal sinus outflow tract (FSOT

Serial No:

Name:

Age:

Sex:

Hospital No:

Address:

Chart review:

Presenting symptoms:

Clinical Diagnosis:

Other systemic diseases:

CT scan view:

Coronal CT scan PNS- FSOT

	RIGHT	LEFT
Frontal sinus (0-normal, 1- hypoplastic, 2- hyperplastic)		
Agger nasi cell (0- absent, 1- present)		
Frontal cells (0- seen, 1- not seen)		
Frontal cells (1- type 1, 2- type 2, 3-type3, 4-type 4)		
Supraorbital ethmoid cell (0- absent, 1- present)		
Interfrontal sinus cell septal cell (0- absent, 1- present)		
Uncinate attachment (types 1,2,3,4,5,6)		

Multipplanar Reconstructed CT scan:FSOT

	RIGHT	LEFT
Frontal sinus (0-normal, 1- hypoplastic, 2- hyperplastic)		
Agger nasi cell (0- absent, 1- present)		
Frontal cells (0- seen, 1- not seen)		
Frontal cells (1- type 1, 2- type 2, 3-type3, 4-type 4)		
Frontal bullar cell (0- absent, 1- present)		
Suprabullar cell (0- absent, 1- present)		
Supraorbital ethmoid cell (0- absent, 1- present)		
Interfrontal sinus cell septal cell (0- absent, 1- present)		
Uncinate attachment (types 1,2,3,4,5,6)		
Anteroposterior diameter of Nasofrontal isthmus in mm		
Transverse diameter		
Area of nasofrontal isthmus (mm ²)		