

**NORMAL VARIANTS OF PARANASAL SINUSES AND THEIR CLINICAL SIGNIFICANCE: A COMPUTED TOMOGRAPHIC EVALUATION**Ravi Ningappa<sup>1</sup>, Pooja Hegde<sup>2</sup>**HOW TO CITE THIS ARTICLE:**

Ravi Ningappa, Pooja Hegde. "Normal Variants of Paranasal Sinuses and their Clinical Significance: A Computed Tomographic Evaluation". Journal of Evolution of Medical and Dental Sciences 2015; Vol. 4, Issue 16, February 23; Page: 2752-2761, DOI: 10.14260/jemds/2015/395

**ABSTRACT:** Chronic rhino sinusitis is one of the most common illnesses of our times and has been known to negatively impact health related quality of life. The importance of anatomic variants as a predisposing cause for sinus disease has been stressed by several authors. Computed tomography is the investigation of choice in the diagnosis of diseases involving the paranasal sinuses and also for the pre-operative assessment of sino-nasal surgery. Aim of this study was to understand the significance of these anatomic variations with respect to disease process affecting the paranasal sinuses and to emphasise on the importance of pre-operative identification of these anatomic variants. **MATERIALS AND METHODS:** All Computed Tomography scans of paranasal sinuses referred to the Department of Radiodiagnosis in our Institute over a period of 18 months, between June 2013 to November 2014. 280 scans of paranasal sinuses done in this period were evaluated retrospectively. We excluded scans in which the paranasal anatomy had been altered / obscured by inflammation, trauma, surgery or neoplasms. Rest of the images were assessed for the presence of variant anatomy involving the paranasal sinuses and their drainage pathways. **CONCLUSION:** In this study variant sinonasal anatomy was noted in 84 % of the cases, with deviated nasal septum and the Agger nasi cells being most common types. Since anatomical variants are so common in paranasal sinuses, familiarity with the complex and highly variable anatomy of the paranasal sinuses is critical to its evaluation at CT.

**KEYWORDS:** Paranasal sinuses, variants, sinusitis

**INTRODUCTION:** All of the paranasal sinuses originate as evaginations from the nasal fossae.<sup>1</sup> These consist of, usually, four paired air-filled spaces, named for the facial bones in which they are located, i.e. frontal, maxillary, ethmoid and sphenoid. Anatomic variation in paranasal sinuses is the rule, rather than an exception.

Chronic rhino sinusitis is one of the most common illnesses of our times and has been known to negatively impact health related quality of life.<sup>2</sup>

The importance of anatomic variants as a predisposing cause for sinus disease has been stressed by several authors. These variations compromise already narrow drainage pathway and produce significant obstruction, although, they do not represent disease states per say.<sup>3</sup>

Computed tomography (CT) of the paranasal sinuses is required for the diagnosis and subsequent treatment of sinusitis as the underlying anatomical variations could possibly be a cause for sinonasal symptoms. Endoscopic sinus surgery (ESS) is the treatment of choice for refractory cases of rhinosinusitis which are not responding to medical treatment. CT demonstrates the extent of disease, significant anatomical variations that may predispose to rhinosinusitis and the nearby vital structures so that iatrogenic damage can be avoided.<sup>2</sup>

**AIMS AND OBJECTIVES:**

1. Discuss the anatomy of the paranasal sinuses and to identify the common anatomical variations encountered during routine reporting of CT scans of paranasal sinuses.
2. To understand the significance of these anatomic variations with respect to disease process affecting the paranasal sinuses.
3. To emphasise on the importance of pre-operative identification of these anatomic variants.

**MATERIALS AND METHODS:**

**SCAN PROTOCOL:** Serial axial sections were taken at 1mm thickness and multiplanar reconstructions done in coronal and sagittal planes, in both soft tissue and bone algorithms.

**INCLUSION CRITERIA:** All Computed Tomography scans of paranasal sinuses referred to the Department of radiodiagnosis in our Institute over a period of 18 months, between June 2013 to November 2014. 280 scans of paranasal sinuses done in this period were evaluated retrospectively.

**EXCLUSION CRITERIA:** Out of the 280 scans reviewed, 130 were excluded because the sinonasal anatomy had been altered or obscured by inflammatory disease of the sinuses, neoplasms, previous surgery, trauma.

Rest 150 CT scans were assessed for the presence of variant anatomy in the paranasal sinuses and their drainage pathways.

**RESULTS:** Among the 150 cases, 84 were males and 66 females. Variant sinonasal anatomy was noted in 84 % of the cases. The anatomic variations in frontal sinuses assessed were the frontal recess cells and their subtypes that was present in 28% of the cases. The intra and extramural pneumatisation of the ethmoid air cells was seen in 70% of the cases, with the Agger nasi cells being most common type. The varying degree of pneumatisation of sphenoid air cell was also studied. Few other entities such as frontal sinus aplasia, nasal septal variations and turbinate variations were also studied.

**DISCUSSION:** Familiarity with the complex and highly variable anatomy of the paranasal sinuses is critical to its evaluation at CT. We shall be discussing the variant anatomy encountered in the four paranasal sinus, their definitions and ways to identify them and also emphasise on the clinical importance.

**FRONTAL SINUSES:** The frontal sinuses arise from one of several outgrowths originating in the region of the frontal recess of the nose. Less commonly, the frontal sinus develops from anterior ethmoid cells of the infundibulum.

Because on the average the frontal sinuses do not reach up into the frontal bone until about the age of 6 years, these sinuses are essentially the only paranasal sinuses that are absent at birth. Their development is quite variable but effectively appears to start only after the second year of life.<sup>4</sup>

**VARIANTS OF FRONTAL SINUSES:**

- **APLASIA:** Absence of pneumatisation in frontal bone results in Aplasia<sup>5</sup>

- **FRONTAL CELLS:** The frontal recess is an inverted funnel like structure within the anterior ethmoid complex through which the frontal sinus drains.<sup>6</sup> The boundaries of the frontal recess are typically formed by the agger nasi cell anteriorly; the lamina papyracea laterally; the most anterior and superior portion of the middle turbinate medially; and the ethmoid bulla, its associated bulla lamella, and the suprabullar cell (if present) posteriorly. The frontal recess may be pneumatized by various anterior ethmoid cells, which are collectively known as frontal recess cells.<sup>7</sup>

Frontal recess cells were identified in 28 % of the cases. The clinical relevance of frontal recess cells lies in their potential for causing frontal sinusitis by obstructing frontal sinus outflow at the level of the frontal recess.<sup>8</sup> Any endoscopic surgical procedure aimed at clearing frontal recess obstruction must address these variant cells; failure to do so may result in surgical failure. For this reason, the radiologist's report must accurately characterize any frontal recess cells present by using standard accepted nomenclature.<sup>7</sup>

**There are four types of frontal cells described under the system known as the Kuhn classification<sup>8</sup>:**

1. **Type 1 frontal recess cell (Fig 1):** They are defined as single anterior ethmoid cells within the frontal recess sitting above the agger nasi cell. These cells do not extend into the frontal sinus.<sup>9,10</sup> They were identified in 37% of the frontal recesses.
2. **Type 2 frontal recess cell (Fig 2):** They are defined as a tier of two or more anterior ethmoid cells sitting above the agger nasi cell<sup>9,10</sup>. They were identified in 17% of the frontal recesses.
3. **Type 3 frontal recess cell (Fig 3):** They are defined as a single massive cell sitting above the agger nasi cell and pneumatizing into the frontal sinus. They were seen in 6% of frontal recesses.<sup>9,10</sup>
4. **Type 4 frontal recess cell (Fig. 4):** They are defined as isolated air cells located within the frontal sinus, bordered anteriorly by the anterior frontal sinus table, with their posterior walls representing free partitions in the frontal sinus. Most often type 4 cells have no identifiable connection to the frontal recess at imaging.<sup>6</sup> These were seen in 1% of the frontal recesses.

It has been observed that frontal mucosal thickening is more prevalent in patients with type 3 and type 4 frontal cells than in those without frontal cells.<sup>11</sup>

Supraorbital ethmoid cells, frontal bullar cells, and suprabullar cells make up the posterior group of frontal recess cells. All of the cells in this group are located along the posterior wall of the frontal recess and are bordered posteriorly or superiorly by the anterior skull base.<sup>9</sup>

1. **Supraorbital ethmoid cells:** are anterior ethmoid air cells that extend superiorly and laterally over the orbit from the frontal recess. These cells represent pneumatization of the orbital plate of the frontal bone posterior to the frontal recess and the frontal sinus. Supraorbital ethmoid cells can obstruct frontal sinus drainage.<sup>7</sup> They were seen in 8% of the scans.

On axial images, the supraorbital ethmoid cell is situated behind the frontal sinus. On coronal images, what appears to be the lateral compartment of a septated frontal sinus is actually a separate supraorbital ethmoid cell located posterior and lateral to the frontal sinus.<sup>7</sup> (Fig 5)

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2. **Frontal bullar cells:** represent pneumatization of the anterior skull base in the posterior frontal recess with extension into the true frontal sinus. They form a portion of the posterior wall of frontal recess. They were seen in 5% of the cases. Frontal bullar cells are best demonstrated at sagittal CT, where they appear as ethmoid cells sitting atop the ethmoid bulla and extending into the frontal sinus.<sup>9</sup>
  
3. **Suprabullar cells:** are nearly identical to frontal bullar cells, with the only distinguishing feature being that suprabullar cells lie entirely below the level of the frontal sinus ostium and do not extend into the frontal sinus. They were seen in 3% of the cases. Like frontal bullar cells, suprabullar cells sit above the ethmoid bulla and form a portion of the posterior wall of the frontal recess.<sup>9</sup> Suprabullar cells are best demonstrated on sagittal CT images. (Fig 6)

The final group of frontal recess cells is the medial type, which is made up of the inter-frontal sinus septal cell. This cell represents pneumatization of the inter-frontal sinus septum; when extensive, such pneumatization can extend into the crista galli. They are rare variants and were seen in 3 cases. These cells drain into the medial frontal recess and can impinge on the frontal sinus ostium. Axial and coronal are the best planes for demonstrating inter-frontal sinus septal cells.<sup>9</sup> (Fig. 7)

**ETHMOID SINUS:** The ethmoid sinuses begin to form in the third to fifth fetal months, when numerous separate evaginations arise from the nasal cavity. The anterior cells are the first to so form as evaginations in the lateral nasal wall in the region of the middle meatus. Posterior cell development follows as evaginations in the superior meatal area.<sup>12</sup>

The ethmoid sinuses are divided into groups of cells by bony basal lamellae that extend laterally to the laminae papyracea and superiorly to the fovea ethmoidalis. The lamellae prevent one group of cells from intermingling with another, but they do not prevent intramural expansion of one group into another.<sup>12</sup>

Intramural expansion of one group into another results in concha bullosa when posterior ethmoid cells extend intramurally to pneumatize the middle turbinate.

There can also be extramural expansion of ethmoid cells outside the ethmoid to invade the frontal, maxillary, and sphenoid sinuses as well as the ascending process of the maxilla and lacrimal bone. Encroaching cells are the rule, and one can find any pattern of intramural and extramural expansion, which should be considered normal variations and not anomalies.<sup>13</sup>

**There are some specific patterns of extramural pneumatization that are of clinical Significance:**

1. **AGGER NASI CELL (Fig. 8):** Anterior ethmoid cells can pneumatize the frontal process of the maxilla adjacent to the anterior attachment of the middle turbinate to the ethmoid crest of the ascending process of the maxilla (the agger nasi). These are known as the agger nasi cells<sup>12</sup>. It was seen in 70% of the cases. When present, agger nasi cells are considered the most anterior of all ethmoid cells<sup>13</sup> and can narrow the frontal recess.<sup>14</sup> Coronal and sagittal reformatted CT images are most helpful in identifying the agger nasi cell. On coronal images, the agger nasi

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appears as a laterally placed sinus below the frontal sinus and anterior to the middle turbinate. Sagittal images demonstrate the anterior location of the air cell.

2. **HALLER CELL (Fig. 9):** Infraorbital ethmoid cells are pneumatized ethmoid air cells that project along the medial roof of the maxillary sinus and the most inferior portion of the lamina papyracea, below the ethmoid bulla and lateral to the uncinate process.<sup>12</sup>
3. **ONODI CELL (Fig. 10):** Onodi cells are the most posterior ethmoid cells, being superolateral to the sphenoid sinus and closely associated with the optic nerve. Their presence may increase the chances of optic nerve injury<sup>15</sup>

**SPHENOID SINUS:** The sphenoid sinuses emerge in the fourth fetal month as evaginations from the posterior nasal capsule into the sphenoid bone. By the age of 10 to 12 years the sinus usually has obtained its adult configuration. The lack of any sinus pneumatization of the sphenoid bone by the age of 10 years should suggest the possibility of “occult” sphenoid bone pathology.<sup>31</sup> This is most commonly seen in diseases that require a large marrow demand to compensate for chronic anemia (Ex. Thalassemia, chronic renal failure etc).<sup>12</sup>

**VARIANTS OF SPHENOID SINUSES:** Depending on the degree of pneumatization, the sinus is classified as:<sup>12</sup>

- 1) **Sellar:** The sinus cavity extends posteriorly to the anterior sella turcica wall and lies under the sella floor. It was seen in 85 % of the cases. (Fig. 12)
- 2) **Presellar:** The sinus cavity extends only to the anterior wall of the sella turcica. (Fig. 11)
- 3) **Non pneumatized:** The sphenoid sinuses do not develop posteriorly enough to reach the anterior sella wall. It was seen in ~1% of the cases.

**MAXILLARY SINUSES:** The maxillary sinus is the first of the paranasal sinuses to form. At approximately the seventieth day of gestation,<sup>12</sup>

For the most part the maxillary sinuses develop symmetrically, with only minor common variations. Unilateral hypoplasia and bilateral hypoplasia occur in 1.7% and 7.2% of people, respectively.<sup>16,17</sup> Hypoplasia of the maxilla results from trauma, infection, surgical intervention, or irradiation to the maxillary that occurs during the development of this bone. These conditions can damage the maxillary growth center, producing a small maxilla and thus a “hypoplastic” sinus. Underdevelopment also occurs in first and second branchial arch anomalies such as Treacher Collins syndrome, mandibulofacial dysostosis, and thalassemia major when the demand for marrow prohibits sinus pneumatization.

**MIDDLE TURBINATE:** Pneumatization of the middle turbinate is called concha bullosa. It may block the infundibulum and cause sinus disease due to defective aeration of the sinuses.<sup>15</sup> (Fig. 14)

Paradoxical middle turbinate is the abnormal curvature of the middle turbinate where the convex surface faces laterally. It may block the drainage pathway of the middle turbinate.<sup>15</sup> (Fig. 14)

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**NASAL SEPTUM:** Malalignment of the components of the adult nasal septum (septal cartilage, perpendicular ethmoidal plate, and vomer) may cause deviation of the nasal septum, deformity of the chondrovomerine articulation, or a septal spur.<sup>12</sup> (Fig. 13)

**OLFACTORY FOSSA:** The depth of the olfactory fossa is determined by the height of the lateral lamella of the cribriform plate. Keros classified the depth into 3 categories.

Type 1 – 1-3mm (Fig. 16)

Type 2 – 4-7mm (Fig. 17)

Type 3 – 8-16mm (Fig. 18)

Type 3 exposes more of the very thin cribriform plate to potential damage from trauma, tumour erosion and local nasal surgery.

**ACKNOWLEDGEMENTS:** Department of Radiodiagnosis, Bangalore Medical College and Research Institute, Bangalore.

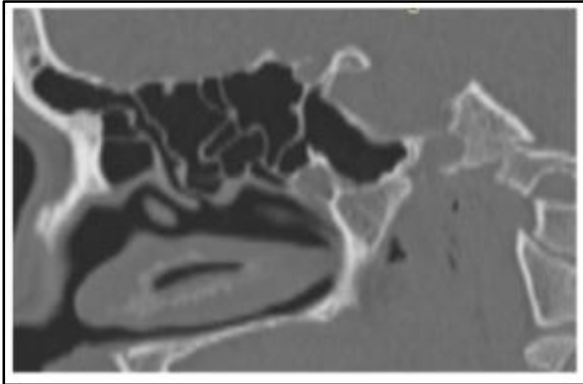
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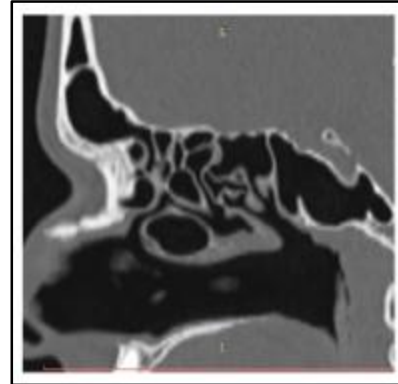


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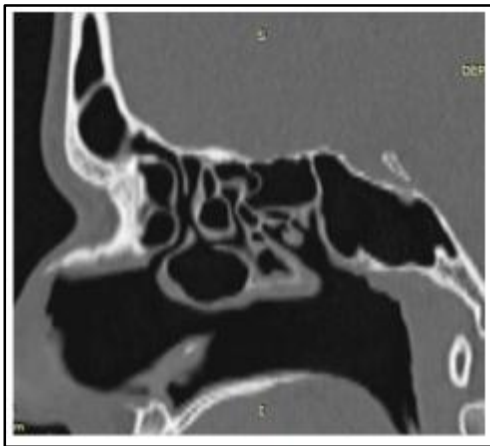
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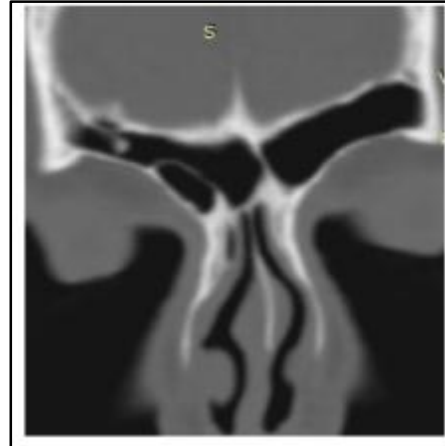
**Fig. 1: Sagittal image showing Type I Kuhn cell**



**Fig. 2: Sagittal image showing type II Kuhn cell**

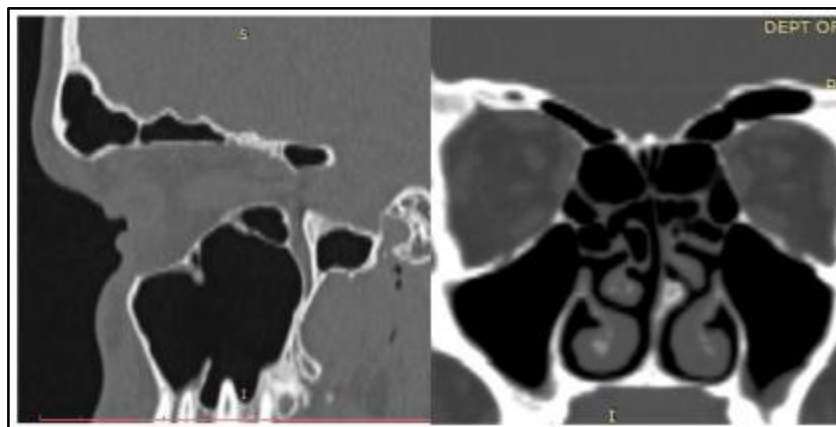


**Fig. 3: Sagittal image showing Type III Kuhn cell**



**Fig. 4: Coronal image showing Type IV Kuhn cell on the right side**

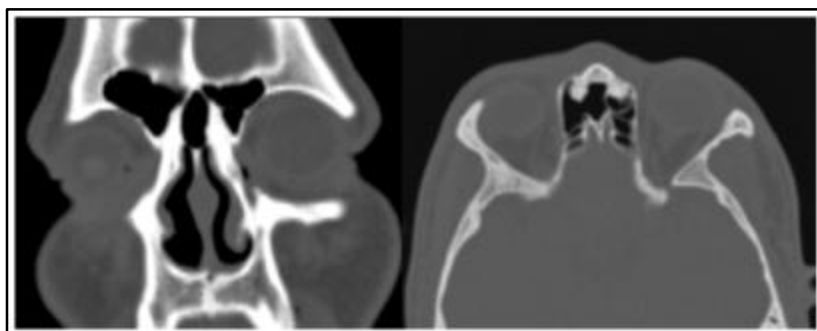
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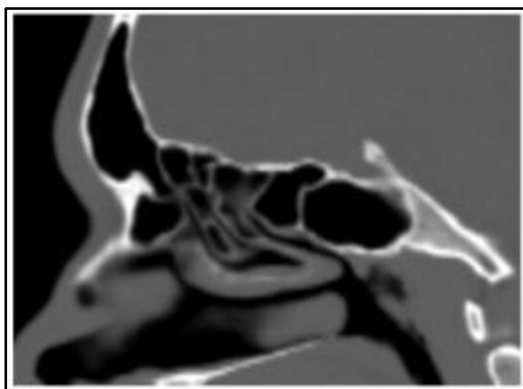
**Fig. 5: Sagittal and Coronal image showing supra-orbital ethmoid cell on the left side**



**Fig. 6: Sagittal image showing Supra-bullar cell**



**Fig. 7: Coronal and axial image showing inter-frontal sinus septal cell**



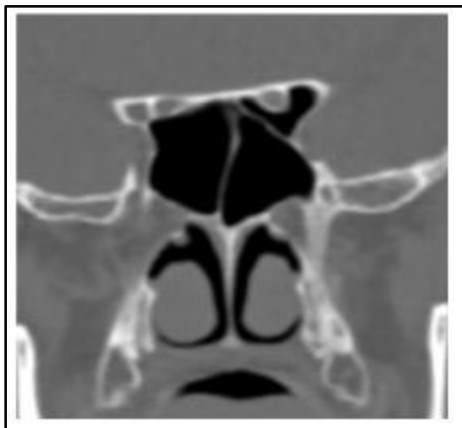
**Fig. 8: Sagittal image showing Agger Nasi cell**



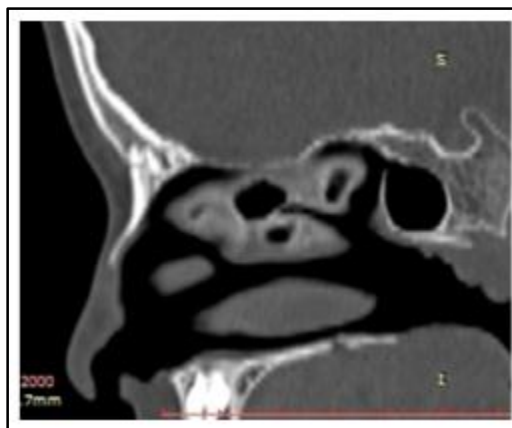
**Fig. 9: Coronal image showing right sided Haller cell**



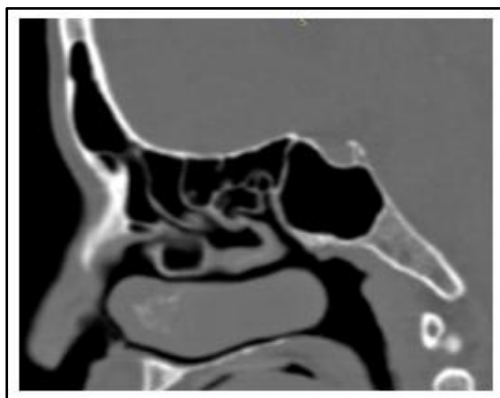
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**Fig. 10: Coronal image showing left Onodi cell**



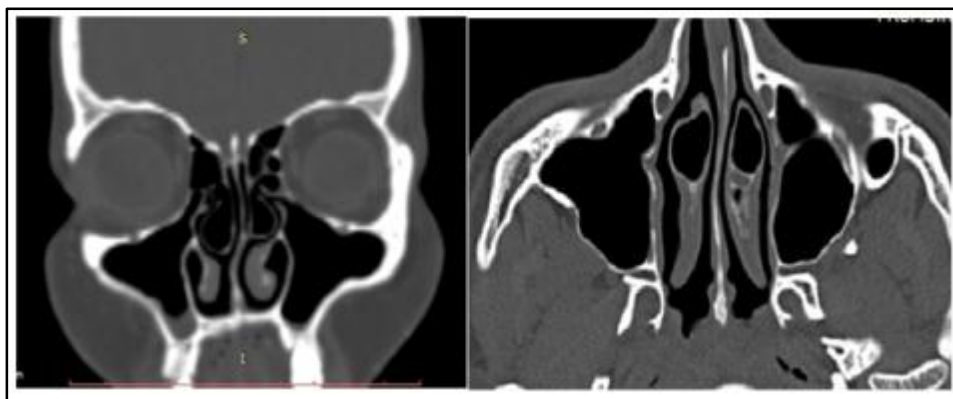
**Fig. 11: Sagittal image showing presellar type of sphenoid sinus**



**Fig. 12: Sagittal image showing sellar type of sphenoid sinus**



**Fig. 13: Sagittal image showing sellar type of sphenoid sinus**



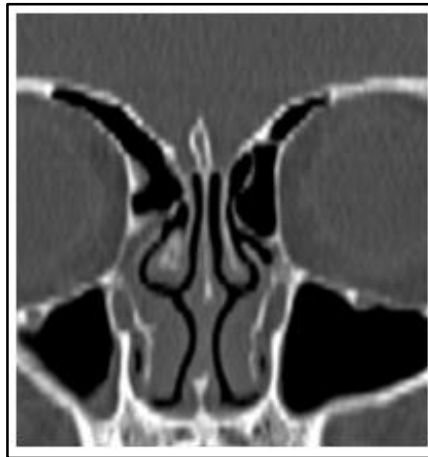
**Fig. 14: Coronal and axial image showing bilateral concha bullosa**



**Fig. 15: Coronal image showing left paradoxical middle turbinate**



**Fig. 16: Coronal image showing Type I olfactory fossa on left side**



**Fig. 17: Coronal image showing Type II olfactory fossa**



**Fig. 18: Coronal image showing Type III olfactory fossa**

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**FINANCIAL OR OTHER**

**COMPETING INTERESTS:** None

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Date of Submission: 24/12/2014.  
Date of Peer Review: 26/12/2014.  
Date of Acceptance: 16/02/2015.  
Date of Publishing: 21/02/2015.