Endoscopic versus Traditional Craniofacial Resection of Sinonasal Tumors

Thesis submitted for partial fulfillment of M.Sc. Degree in Otorhinolaryngology

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Abstract

Reconstruction purposes to attain a watertight seal between the intracranial space and the upper respiratory system thus preventing CSF leak, brain herniation and meningitis. Advances in surgical technique and reconstruction have made larger and more complex lesions amenable to surgical resection. Close and constant cooperation between the neurosurgeon, otolaryngologist, and pathologist is absolutely necessary to the benefit of the patient. The decision for type of approach depends on the training of the surgeon, available resources, and tumor histology and structures involved. This is a retrospective study that was performed at the otorhinolaryngology departement, Kasr El-Aini Hospital, Cairo University during the period from October 2007 to December 2011. It included 12 patients whom presented to the outpatient clinic with a clinical diagnosis of sinonasal mass extending to anterior skull base. They were distributed and subdivided into two groups; Group (A) included 6 patients who were subjected to TCFR. Group (B) included 6 patients who had ECFR. The most common malignant histopathological types were olfactory neuroblastoma. Angiofibroma was the most common benign tumor.

Key word: CFS-ECFR-TCFR-sinonasal tumors-craniofacial –dura –scalp –the maxillary sinus
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<tr>
<td>3D</td>
<td>3 Dimension</td>
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<tr>
<td>AIDS</td>
<td>Acquired Immune Deficiency Syndrome</td>
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<td>AJCC</td>
<td>American Joint Committee on Cancer</td>
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<td>CFR</td>
<td>Craniofacial Resection</td>
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<td>Cm</td>
<td>Centimeter</td>
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<td>CNS</td>
<td>Central nervous System</td>
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<td>CSF</td>
<td>Cerebrospinal fluid</td>
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<td>CT</td>
<td>Computed Tomography</td>
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<td>CVA</td>
<td>Cerebrovascular accident</td>
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<td>DVT</td>
<td>Deep venous thrombosis</td>
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<td>ECFR</td>
<td>Endoscopic Craniofacial Resection</td>
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<td>HPV</td>
<td>Human papilloma virus</td>
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<tr>
<td>I</td>
<td>Olfactory</td>
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<tr>
<td>ICA</td>
<td>Internal carotid artery</td>
</tr>
<tr>
<td>ICU</td>
<td>Intensive Care Unit</td>
</tr>
<tr>
<td>II</td>
<td>Optic</td>
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<tr>
<td>IX</td>
<td>Glossopharyngeal</td>
</tr>
<tr>
<td>Mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>NSF</td>
<td>Nasoseptal Flap</td>
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<td>ONB</td>
<td>Olfactory Neuoroblastoma</td>
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<tr>
<td>PNS</td>
<td>Paranasal Sinuses</td>
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<tr>
<td>SCC</td>
<td>Squamous Cell Carcinoma</td>
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<td>TCFR</td>
<td>Traditional Craniofacial Resection</td>
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<td>VI</td>
<td>Abducent</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>X</td>
<td>Vagus</td>
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<td>XI</td>
<td>Accessory</td>
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<td>Hypoglossal</td>
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Anatomy of Paranasal Sinuses

The anatomy of the paranasal sinuses is complex and varies greatly between human subjects. Understanding this anatomy is, however, imperative for otolaryngologists who wish to avoid surgical complications as each and every one of the paranasal sinuses are in close proximity to critical orbital and skull base structures (Stammberger, 1989).

The literature on the anatomy and physiology of the sinuses extends back to Galen (AD 130–201) who referred to the “porosity” of the bones of the head. Leonardo Da Vinci (1452–1519), whose classical sections of the head illustrate the maxillary antrum and the frontal sinus, apparently recognized the existence of these cavities as separate functional entities. He referred to the maxillary sinus as “the cavity of the bone which supports the cheek.” Highmore (1651) was the first to give a detailed description of the maxillary antrum (antrum of Highmore) (Blanton and Biggs, 1969).

However, it was only in the late nineteenth century that the first detailed and systematic anatomical and pathological descriptions of the paranasal sinuses were published by Zuckerkandl. These descriptions became even more valuable as they could be applied directly to patients and their problems. The invention of computed tomography (CT) which was available since the mid-1970s, made again the relationship between the largest sinuses and the ethmoids very clear, applying the knowledge that had been developed more than 100 years ago. Comparisons of CT with the drawings of Onodi, Grunwald and Zuckerkandl demonstrate the incredible accuracy of these pioneers’ knowledge (Stammberger, 1989).

From an evolutionary point of view, the paranasal sinuses are convexities of the nasal cavity into the neighbouring bone. Their mucosa are a continuation of the nasal mucosa; thus, a close relation exists between the varying paranasal sinuses. They are very variable with regards to dimension and shape (Lang, 1998).

Each one is named after the skull bone in which it is located (Van Cauwenberge et al., 2004). All sinuses are lined by a respiratory pseudostratified epithelium, composed of four major types of cells:

1. Ciliated columnar cells
2. Nonciliated columnar cells
3. Goblet type mucous cells
4. Basal cells

This mucosa is directly attached to bone and is referred to as mucoperiosteum. Although it is somewhat thinner, the mucoperiosteum of the sinuses is continuous with that of the nasal cavity through the various ostia of the sinuses (Stammberger, 1989).

The paranasal sinuses form a complex unit of four paired air-filled cavities at the entrance of the upper airway. They start developing from ridges and furrows in the lateral nasal wall as early as the eighth week of embryogenesis, and they continue their
pneumatization until early adulthood. However, during the development of a sinus, pneumatization may involve adjacent bones, as is the case for the ethmoid sinus developing into the frontal, maxillary or sphenoid bone, and for the maxillary sinus extending into the zygomatic bone (Bodino et al., 2004).

Frontal Sinus and Recess

The frontal sinuses are funnel-shaped cavities that show marked individual variation. There is usually a central septum dividing the frontal sinus into two parts but several septa may also be seen (Rasper, 1936).

Development of the frontal recess and frontal sinus starts early in fetal life and continues into the teenage years. The multiple cells that can pneumatize the frontal bone all maintain a separate communication with the frontal recess. The frontal sinus itself may develop as an extension of the frontal recess, from extension of an anterior ethmoid cell, or from extension of the ethmoid infundibulum. The pneumatization patterns of the various cells impact the size, location, and shape of the frontal sinus outflow tract. The development is variable, leading to the complexity of the anatomy in this region (Jacobs, 1997).

At birth, the frontal sinus is a small blind pouch often indistinguishable from the anterior ethmoid cells. Starting around 2 years of age, pneumatization of the frontal sinus will become significant in early adolescence, and complete in the late teens. The right and left frontal sinuses develop independently, and are often asymmetrical: As with the sphenoid sinus, it is not uncommon to find one “dominant” frontal sinus, one or two hypoplastic frontal sinuses, one aplastic frontal sinus, and more rarely bilaterally aplastic sinuses (Kuhn et al., 1991).

The frontal sinus lies within the frontal bone between a thick anterior table and a relatively thin posterior table, separating the sinus from the frontal lobe of the brain posteriorly. It has classically been described as a pyramid: its medial wall corresponds to a bony septum, the intersinus septum, which can sometimes be pneumatized, forming an intersinus cell. The floor of the frontal sinus corresponds to the anterior roof of the orbit, and the thin bone at this level, in a similar way as the posterior table, can be eroded by a mucocele (Kuhn et al., 1991).

The paired frontal sinuses situated posterior to the superciliary arches. Each usually underlies a triangular area on the surface, its angles formed by the nasion, a point 3 cm above the nasion and the junction of the medial third and lateral two-thirds of the supraorbital margin. Their arterial supply is from the supraorbital and anterior ethmoidal arteries and their venous drainage is into the anastomotic vein in the supraorbital notch connecting the supraorbital and superior ophthalmic veins. Lymphatic drainage is to the submandibular nodes. The nerve supply is from the supraorbital nerve (Lee et al., 2004).
Dimension and form of the frontal sinuses vary greatly. They may be totally absent (aplasia) or extend asymmetrically into the orbital roof. In the latter case, they may even reach the anterior margin of the lesser wing of the sphenoid bone. Laterally, the frontal sinus can extend as far as the zygomatic process of the frontal bone and occasionally comprise the lateral orbital wall. The roof of the frontal sinus partially constitutes the floor of the anterior cranial fossa. The extent of the frontal sinus in the orbital roof section of the frontal bone is particularly important during surgery, when approaching the orbit from the anterior cranial fossa (Lang, 1998).

The frontal sinus drains into the middle meatus and nasal cavity through a complex passage. “nasofrontal duct” that forms the nasofrontal connection. The frontal recess is the most anterosuperior aspect of the anterior ethmoid sinus that forms the connection with the frontal sinus (Stammberger et al., 1995).

The frontal recess, the drainage pathway of the frontal sinus, usually drains into the middle meatus (62%) or into the ethmoid infundibulum (38%) (Chong et al., 1998).

The frontal recess serves as an antechamber to the frontal sinus and is bounded by the lamina papyracea laterally, the middle turbinate and cribriform plate medially, the nasofrontal beak anteriorly, and the ethmoid bulla and skull base posteriorly (Lee et al., 1997).

The frontal recess may communicate with the suprabullar recess If the anterior wall of the ethmoid bulla does not reach the skull base and form a complete posterior wall (Stammberger et al., 1995).

And depending on the anterior insertion of the uncinate process, the frontal recess will drain medial or anterior to the uncinate (when it inserts on the lamina papyracea) and lateral or posterior to the uncinate into the anterior ethmoid (when the uncinate inserts on the skull base or on the middle turbinate (Lee et al., 1997).

There is tremendous variation with respect to the pattern of the nasofrontal connection. The anatomic complexity of this region is better understood when the effect of the surrounding ethmoid cells, such as the agger nasi cell, frontal cells, and supraorbital ethmoid cells, are considered.

An intimate relationship exists between the agger nasi cell and the frontal recess. Secretions from the frontal sinus destined for the nasal cavity usually follow a path through the frontal recess and over the posterior and medial surface of the agger nasi cell. If the agger nasi cell is extensively pneumatized, the frontal recess can be relatively narrowed, and hence the patient may be predisposed to frontal sinusitis. In surgery, an extensively pneumatized agger nasi can be mistaken for the frontal recess or sinus. If a large agger nasi cell is opened and mistaken for a frontal sinus, the residual superoposterior wall of the agger nasi cell can scar posteriorly to the ethmoid roof, and iatrogenic stenosis or obstruction of the nasofrontal connection can occur (Kuhn et al., 1991).

In addition to the agger nasi cell, there are other ethmoid cells that have an intimate relationship with the frontal recess. Van Alyea (1941) reported that approximately 50% of anatomic specimens had anterior ethmoid cells that encroached into the frontal sinus,
Anatomy of Paranasal Sinuses & Craniofacial area

and that one-third of these encroached into the area of the frontal ostium. He termed these cells "frontal cells".

The major cell types found in the frontal recess include agger nasi cells, frontal cells (types I–IV), supraorbital ethmoid cells, suprabullar cells, and intersinus septal cells. The agger nasi cell is the most constant of the frontal recess cells, while other cell types have wider variability in their prevalence (Lee et al., 2004).

**Bent and Kuhn, (1994)** classified the frontal cells into four types:

1. Type 1 is a single air cell above the agger nasi.
2. Type 2 is a group of small cells above the agger nasi but below the orbital roof.
3. Type 3 is a single cell extending from the agger nasi into the frontal sinus.
4. Type 4 is an isolated cell within the frontal sinus not contiguous with the agger nasi.

The keys to achieving a good and safe visualization of the frontal sinus are opening the agger nasi cells and palpating with a probe to identify the posterior wall of the frontal sinus away and in front of the anterior ethmoid artery infundibulum (Bent et al., 1994).

The roof of the suprabullar and agger nasi cells should be down-fractured and removed carefully to visualize the infundibulum (Bent et al., 1994).

The supraorbital ethmoid cell is another anatomic variation in the region of the frontal recess. Supraorbital ethmoid cells commonly occur from pneumatization of the orbital plate of the frontal bone by ethmoid air cells. Kasper (1963) felt that these cells originated in the third and fourth frontal furrow regions, from which they pneumatized laterally and superiorly over the orbit into the orbital plate of the frontal bone. Pneumatization of the orbital plate of the frontal bone can also occur, however, from the frontal sinus proper. In such cases, the embryologic region that pneumatizes the cortex of the frontal bone between the anterior and posterior tables can also pneumatize the orbital plate of the frontal bone (Anderson, 1978).

The ventilation and drainage of the frontal sinus and the pneumatized orbital plate would therefore be through a common ostium at the frontal recess.

Kasper (1963) has described such pneumatization as originating solely from the second frontal furrow. In such cases, opening the frontal recess would provide drainage to the entire region.

Stammberger (1989) states that the supraorbital cell is an anatomic variation that develops as an extension from the posterior aspect of the frontal or suprabullar recess.
The Ethmoid sinus

The ethmoid sinus is referred to as the ethmoid labyrinth because of the complexity of its anatomy, due to the honeycomb-like appearance of its air cells with intricate passageways and blind alleys. Rhinologists have tried to simplify its difficult anatomy by considering the sinus as a series of five obliquely oriented parallel lamellae. These derive from the ridges in the lateral nasal wall of the fetus called ethmoturbinals. The lamellae are relatively constant and easy to recognize intraoperatively.

The first and most anterior lamella corresponds to the uncinate process, which embryologically represents the basal lamella of the first ethmoturbinal. The second lamella is the ethmoid bulla, or bulla ethmoidalis, the largest and most constant anterior ethmoid cell. The most important lamella is the third one, the ground or basal lamella of the middle turbinate. It divides the ethmoid labyrinth into its anterior and posterior components. The fourth lamella is the basal lamella of the superior turbinate and the fifth is the basal lamella of the supreme turbinate (Polavaram et al., 2004).

At birth, only a few cells are pneumatized, but in adulthood their number can go beyond 15 cells (Stammberger and Kennedy, 1995).

The width of the ethmoid increases from anterior to posterior because of the conelike structure of the orbit. The ethmoid measures about 3–4 cm in length, 2–2.5 cm in height and 0.5–1.5 cm in width (Lang, 1987).

The ethmoidal cells border medially on the nasal cavity, caudally on the maxillary sinus, and cranially on the frontal sinus and the anterior cranial fossa respectively. The orbital boundary is formed anteriorly by the lacrimal bone, posteriorly by the papyraceous lamina of the ethmoid and caudally by the maxillary complex. The sphenoid is attached posteriorly. The ethmoid labyrinth is composed of a system of partially disjoined chambers, which one can divide into an anterior and posterior ethmoidal cell system according to their position (Stammberger, 1989).

The arterial supply is from the sphenopalatine artery and the anterior and posterior ethmoidal arteries; their venous drainage is by the corresponding veins. The lymphatics of the anterior and middle groups drain to the submandibular nodes, and those of the posterior group to the retropharyngeal nodes. The innervation is from the anterior and posterior ethmoidal nerves (sensory supply), and from orbital branches of the pterygopalatine ganglion (parasympathetic secretomotor fibers) (Kantarci et al., 2004).

Anterior Ethmoidal air cell

Agger Nasi

The agger nasi cells are the most anterior ethmoid cells, and are endoscopically visualized as a prominence anterior to the insertion of the middle turbinate. From Latin, agger means mound or eminence, and agger nasi refers to the pneumatized superior
remnant of the first ethmoturbinal which persists as a mound anterior and superior to the
insertion of the middle turbinate. Rarely, the pneumatization can extend inferiorly to
involve the anterosuperior part of the uncinate process, which derives from the
descending portion of the first ethmoturbinal. The agger nasi pneumatization can also
have a significant impact on the uncinate process insertion, as well as on the patency of
the frontal recess. Accurate identification of the agger nasi is the key to the surgical
access to the frontal recess (Wormald, 2003).

This cell usually takes its origin from the superior aspect of the infundibulum or the
frontal recess region.

The agger nasi cell is bordered anteriorly by the frontal process of the maxilla,
superiorly by the frontal recess/sinus, anterolaterally by the nasal bones, inferomedially
by the uncinate process of the ethmoid bone, and inferolaterally by the lacrimal bone.

The intimate relationship of the cell to the lacrimal bone readily explains the
finding of epiphora in selected patients with sinus disease. The agger nasi can also be
important in frontal sinusitis and its treatment. The superior aspect of the cell serves as
the anteromedial floor of the frontal sinus and a significant portion of the anterior border
of the frontal recess. This is relevant for understanding the pathophysiology of frontal
sinusitis and the surgical treatment of the frontal sinus. The agger nasi can pneumatize
inferomedially to pneumatize the uncinate process (Stammberger et al., 1995).

**Uncinate Process**

This uncinate process is nearly sagittally oriented, nearly paralleling the ethmoidal
bulla. It is approximately 3 to 4 mm wide and 1.5 to 2 cm in length. Its posterior margin
is free as it has no bony attachments. Anteriorly and superiorly, it attaches to the
ethmoidal crest of the maxillae. Posteriorly and inferiorly, the uncinate attaches to the
ethmoidal process of the inferior turbinate bone. The attachment here is thick, and the
uncinate often splits or widens in this region to fuse with the stouter inferior turbinate
bone. The uncinate projects posterior and superior to the middle turbinate attachment and
most commonly bends laterally to insert on the lamina papyracea of the orbit.
Alternatively, the uncinate can attach centrally to the skull base or medially to the
superior aspect of the vertical lamella of the middle turbinate near the turbinate’s
insertion to the cribriform plate (Stammberger et al., 1995).

Stammberger (1995) highlights that the superior portion of the uncinate is divide
to attach to the lamina papyracea, skull base, and middle turbinate (Fig. 1). The uncinate
has no bony attachment anterior and posterior to its attachment to the inferior turbinate
bone. Here, the lateral nasal wall is made not of bone but rather middle meatal mucosa, a
small layer of intervening connective tissue, and sinus mucosa. These areas are referred
to as the anterior and posterior fontanelles.

The posterior fontanelle corresponds to the area between the tails of the middle and
inferior turbinates, behind the hiatus semilunaris and under the ethmoid bulla. The
posterior fontanelle can have an opening to the maxillary sinus, the accessory ostium,
which could be mistaken for the natural ostium during endoscopic sinus surgery if an
incomplete uncinectomy is performed. A smaller anterior fontanelle is located between
the anterior part of the uncinate superiorly and the insertion of the inferior turbinate inferiorly.

It is a very important surgical landmark in the lateral nasal wall for endonasal sinus surgery. Although considered part of the ethmoid labyrinth since it derives from the descending portion of the first ethmoturbinal, the uncinate process is typically discussed when addressing the maxillary sinus because of its intimate relationship with the maxillary ostium.

The uncinate process can be displaced medially by polypoid disease or laterally against the orbit as in maxillary sinus hypoplasia.

Removing the uncinate process is the first step of most endoscopic sinus surgeries. When performing this, one must keep in mind the anterior insertion of the uncinate process in order to avoid injuries to the medial orbital wall (lamina papyracea). This step usually reveals the natural ostium of the maxillary sinus. The superior border of the maxillary sinus ostium identifies the level of the orbital floor (Bolger and Kennedy, 1992).

The most common orientation of the uncinate to the lateral wall and lamina papyracea is approximately 140°; however, there is a significant amount of variability (Yousem, 1993).

**Fig. 1:** The superior attachment of the uncinate process (A) most commonly laterally to the orbit, (B) medially to middle turbinate, (C) centrally to the skull base (Kennedy et al., 2001).

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**Ethmoid Bulla**

The ethmoid bulla is one of the most constant and largest of the anterior ethmoid air cells. It is located within the middle meatus directly posterior to the uncinate process and
anterior to the basal lamella of the middle turbinate. The cell is based on the lamina papyracea and projects medially into the middle meatus. The cell has the appearance of a bulla, that is, a hollow, thin-walled, rounded, bony prominence. Superiorly, the anterior wall of the ethmoid bulla can extend to the skull base and form the posterior limit of the frontal recess. Posteriorly, the bulla can blend with the ground lamella.

Rarely, when nonpneumatized, a bony projection from the lamina papyracea results and is referred to as the torus lateralis (Polavaram et al., 2004).

**Hiatus Semilunaris**

It’s a crescent-shaped gap between the posterior-free margin of the uncinate process and the anterior wall of the ethmoid bulla. It is through this two-dimensional, sagittally oriented cleft or passageway that the middle meatus communicates with the ethmoid infundibulum; the passageway through which the middle meatus communicates with the lateral sinus (retro and suprabullar recess) (Stammberger et al., 1995).

**Ethmoidal Infundibulum**

It is the funnel-shaped passage through which the secretions from various anterior ethmoid cells, the maxillary sinus, and, in some cases, the frontal sinus are transported or channeled into the middle meatus. The ethmoidal infundibulum is a three-dimensional space located in the anterior ethmoid region, bordered medially by the mucosa-covered uncinate process, laterally by the lamina papyracea, and anteriorly and superiorly by the frontal process of the maxilla and lacrimal bone superolaterally.

The ethmoidal infundibulum communicates with the middle meatus through the hiatus semilunaris (Stammberger et al., 1995).

**Sinus Lateralis (Suprabullar and Retrobullar Recesses)**

It lies behind and above the ethmoid bulla, is bordered by the ethmoid roof superiorly, the lamina papyracea laterally, the ethmoid bulla roof and posterior wall inferiorly and anteriorly, and the basal lamella of the middle turbinate posteriorly.

These are anterior ethmoid cells that arise immediately behind the frontal recess and extend over the orbit through pneumatization of the orbital plate of the frontal bone. They can compromise posteriorly the frontal sinus drainage.

During endoscopic sinus surgery, supraorbital cells can be mistaken for the frontal sinus by inexperienced surgeons. Transillumination of these cells with a telescope reveals the light in the inner canthal area, rather than the supraorbital area when the frontal sinus is transilluminated (Polavaram et al., 2004).
Ostiomeatal Unit

Several middle meatal structures: the uncinate process, the ethmoid infundibulum, anterior ethmoid cells, and ostia of the anterior ethmoid, maxillary, and frontal sinuses is a functional rather than an anatomic designation (Naumann, 1965).

Haller cells

They are ethmoid cells that extend along the floor of the orbit-roof of the maxillary sinus, inferolateral to the ethmoidal bulla. They vary in size and when large can narrow the ostium of the maxillary sinus or the ethmoid infundibulum.

It arises from the anterior ethmoid in 88% and the posterior ethmoid in 12% (Kainz et al., 1993).

Posterior Ethmoid Sinus

It's a collection of one to five ethmoid cells that drain into the superior and supreme meati as they are developmentally derived from the second and third primary furrows.

The posterior ethmoid sinus is bounded anteriorly by the basal lamella of the middle turbinate, posteriorly by the anterior wall of the sphenoid sinus, laterally by the lamina papyracea, medially by the vertical portions of the superior and supreme turbinates and their accompanying meati, and superiorly by the ethmoid roof.

The posterior ethmoids have specific surgical significance due to their proximity to the skull base and optic nerve.

Onodi (1910) performed detailed investigations of the variability in posterior ethmoid anatomy, and he specifically highlighted the relationship the “most posterior ethmoid cell” could have with the optic nerve.

The sphenoethmoid cells, or Onodi cells, are important group of ethmoid cells in which the posterior ethmoid cells extend superiorly or laterally to the sphenoid sinus, and the pneumatization can reach the posterior clinoid process. The sphenoethmoid cell is intimately related to the optic nerve, whether the latter is prominent or not in its lateral wall. Also, if large enough, the carotid artery can bulge through its posterior wall. Thus, attempts to open the sphenoid through a sphenoethmoid cell can result in serious damage to the optic nerve or the carotid artery. These important structures are usually related to the lateral wall of the sphenoid sinus; however, accurate identification of these structures and possibly Onodi cells on a preoperative CT scan is the best way to avoid such severe complications (Kantarci et al., 2004).

Ethmoid Roof

The frontal bone sends an extension across the ethmoids, which are open superiorly, to join with the lateral lamella of the cribriform plate. The extension of frontal bone forms the ethmoid roof.
The anterior and posterior ethmoid arteries, terminal branches of the internal carotid artery via the ophthalmic artery, run along the roof of the ethmoid from lateral to medial (Stammberger and Kennedy, 1995).

The ethmoid roof may vary in its orientation from being nearly horizontal to nearly vertical; however, in most patients, the ethmoid roof lies above the level of the cribriform plate. The medial aspect of the ethmoid roof is formed by the lateral lamellae of the cribriform plate, also known as the lamina lateralis of the lamina cribrosa because it projects superiorly. Keros (1980) has described three types of skull-base conformations that have clinical relevance in sinus surgery.

In type one, the olfactory sulcus is 1 to 3 mm deep, the corresponding lateral lamella is short, and there is a significant portion of frontal bone that backs the ethmoid roof, making the roof thick and the sinus less hazardous to operate in. In type two, the olfactory sulcus is 3 to 7 mm deep, and the corresponding lateral lamella forms a considerable portion of the medial ethmoid roof. In type three, the olfactory sulcus is 7 to 16 mm deep, and the ethmoid roof lies at a significant level above the cribriform plate (Fig. 2). The thin lateral lamella is a much larger component of the roof, and a significant portion of the ethmoid roof is not backed by thick frontal bone, making this the most hazardous sinus to operate in (Kainz and Stammberger 1988).

Fig. 2: Variable position of the cribriform plate in comparison with the roof of the ethmoid. 1- Crista galli, 2- Cribriform plate, 3- Os frontale, 4- Ethmoid, 5- Concha mediale, 6- Lateral lamina, 7- Sinus frontalis, 8- Sinus Ethmoidalis (Probst, and Tomashett, 1990).
Sphenoid bone

It is located centrally within the skull, and forms the posterior connection between the mid-facial skeleton and the cranial base, whereas the ethmoid bone, which has a delicate honeycombed structure, forms the anterior connection (Van Cauwenberge et al., 2004).

Antero-laterally the sphenoid connects to the zygomatic bone and antero-inferiorly via the pterygoid process it connectes to the pyramidal process of the palatine bone.

Their arterial supply is via the posterior ethmoidal artery and venous drainage through the corresponding vein; lymph drainage is to the retropharyngeal nodes and the nerve supply arises from the posterior ethmoidal nerves (sensory) and orbital branches of the pterygopalatine ganglion (parasympathetic secretomotor) (Kantarci et al., 2004).

The sphenoid sinuses

The sphenoid sinuses are located at the skull base at the junction of the anterior and middle cerebral fossae. Their growth starts between the third and fourth months of fetal development, as an invagination of the nasal mucosa into the posterior portion of the cartilaginous nasal capsule. Between birth and 3 years of age, the sphenoid is primarily a pit in the sphenoethmoid recess. Pneumatization of the sphenoid bone starts at age three, extends toward the sella turcica by age seven, and reaches its final form in the the midteens (Van Cauwenberge et al., 2004).

The two sinuses generally develop asymmetrically, separated by the intersinus bony septum. In some cases, because of this asymmetry, the intersinus septum goes off the midline and can have a posterior insertion on the bony carotid canal, in the lateral wall of the sphenoid. For this reason, care must be taken when removing the septum in these cases, as a brisk avulsion may result in carotid rupture (Sethi et al., 1995).

Pneumatization of the sphenoids can invade the anterior and the posterior clinoid processes as well as the posterior part of the nasal septum, the Vomer. The sphenoid sinus drains through a single ostium into the sphenoethmoid recess: this ostium is classically situated 7 cm from the base of the columella at an angle of 30° with the floor of the nose in a parasagittal plane, and this usually corresponds to a location halfway up the anterior wall of the sinus. Endoscopically, the posteroinferior end of the superior turbinate points superiorly and medially toward the ostium and thus represents a very important landmark to identify it (Kim et al., 2001).

The superior wall of the sphenoid sinus usually represents the floor of the sella turcica. Depending on the extent of pneumatization, the sphenoid sinus can be classified into three types:

1. Conchal: the area below the sella is a solid block of bone without pneumatization.
2. Presellar: the sphenoid is pneumatized to the level of the frontal plane of the sella and not beyond.

3. Sellar: the most common type, where pneumatization extends into the body of the sphenoid beyond the floor of the sella, reaching sometimes the clivus.

The lateral wall of the sphenoid sinus can show various prominences, the most important being the carotid canal and the optic canal:

The internal carotid artery is the most medial structure in the cavernous sinus, and rests against the lateral surface of the sphenoid bone. Its prominence within the sphenoid varies from a focal bulge to a serpigenous elevation marking the full course of the intracavernous portion of the carotid artery from posteroinferior to posterosuperior (Fig. 3). In some cases, even without advanced sinus disease, dehiscence in the bony margin can be present, and this should be particularly looked for on the CT scan (Sethi et al., 1995).

The optic canal is found in the posterosuperior angle between the lateral, posterior and superior walls of the sinus, horizontally crossing the carotid canal from lateral to medial (Fig. 3). Pneumatization of the sphenoid above and below the optic canal can result, respectively, in a supraoptic recess and an infraoptic recess (the opticocarotid recess). The infraoptic recess lies between the optic nerve superiorly and the carotid canal inferiorly, and can sometimes pneumatize the anterior clinoid process.

The canals of two other nerves can be encountered in the lateral wall of the sphenoid sinus, below the level of the carotid canal: The second branch of the trigeminal nerve superiorly through the foramen rotundum, the vidian nerve in the pterygoid canal inferiorly (Fig. 3). In some cases, these nerves are easily identified on a coronal CT scan defining the superior and the inferior borders of the entry into the so-called lateral recess in an extensively pneumatized sphenoid sinus (Kim et al., 2001).

**Fig. 3**: Simplified drawing of a lateral wall of the left sphenoid sinus. 
(A) Optic canal, (B) Carotid prominence, (C) The canals for the second branch of the trigeminal nerve, (D) The vidian nerve (Kim et al., 2001).
The Maxillary Sinus

The maxillary sinus is the largest and most constant of the paranasal sinuses. It is the first sinus to develop in utero. After birth, it undergoes two periods of rapid growth, between birth and 3 years of life, then between ages 7 and 18 years. The maxillary sinus has a pyramidal shape with an anterior wall corresponding to the facial surface of the maxilla. Its posterior bony wall separates it from the pterygomaxillary fossa medially and from the infratemporal fossa laterally. Its medial wall is formed by the middle meatus mucosa, a layer of connective tissue and the sinus mucosa.

The floor of the maxillary sinus is formed by the alveolar process of the maxillary bone and the hard palate. It lies at the same level of the floor of the nose in children, and 5–10 mm under the floor of the nose in adults.

The roof of the maxillary sinus corresponds to the floor of the orbit, and frequently shows a posteroanterior bony canal for the distal part of the second branch of the trigeminal nerve (Van Cauwenberge et al., 2004).

It is usually a single chamber; its ostium is located within the most posteroinferior one-third of the infundibulum in the infraorbital ethmoidal cells or Haller’s cells (Kainz et al., 1993).

They can in some cases compromise the patency of the maxillary sinus infundibulum, and in other cases can be involved in the chronic polypoid disease, which will mandate opening them. In addition to this, removing the infraorbital ethmoid cell will allow an accurate identification of the floor of the orbit and the posterior wall of the maxillary sinus, which represent reliable surgical landmarks in the presence of advanced disease or distortion of the middle meatal anatomy (Polavaram et al., 2004).

Anatomic variation is hypoplasia or atelectasis of the maxillary sinus. In this variation, the maxillary sinus is smaller, the surrounding maxillary bone is thicker, and the uncinate process is hypoplastic and lies against the inferomedial orbit (Bolger and Kennedy, 1992).

The blood vessels are the facial, infraorbital and greater palatine arteries and veins; lymph drainage is to the submandibular nodes and the nerve supply is derived from the infraorbital and the anterior, middle and posterior superior alveolar nerves (Kantarci et al., 2004).

The Middle turbinate

The middle turbinate has a complex bony attachment. Anteriorly, it is attached superiorly vertically to the lateral aspect cribriform plate in the agger nasi region. Posteriorly, it swings laterally into the coronal plane and attaches itself to the lamina papyracea. This coronal portion of the middle turbinate is called the basal lamella or ground lamella. The lamella basalis divides the ethmoid cells into the anterior and posterior ethmoid cells. The middle turbinate continues posteriorly in an axial plane,