“GROSS AND ENDOSCOPIC ANATOMY OF SPHENOID AIR SINUS IN CADAVERS AND ADULTS OF NORTH KARNATAKA - A CROSS SECTIONAL STUDY”

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Under the Guidance of

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LIST OF ABBREVIATIONS USED

AP-	Anteroposterior
SO-	Sphenoid Ostium
cm-	Centimeter
FESS-	Functional Endoscopic Sinus Surgery
SS-	Sphenoid sinus
CT-	Computerized tomography
PNS-	Paranasal sinus
MRI-	Magnetic Resonance Imaging
ISS-	Inter-sinus septa
MRA-	Magnetic Resonance Angiography
SNM-	Sinonasal malignancy
CSF-	Cerebrospinal fluid
DCR-	Dacryocystorhinoplasty

ABSTRACT

Introduction –

Sphenoid sinus is most inaccessible paranasal sinus. It has got importance due to trans-sphenoid approach to the pituitary gland. It is surrounded by internal carotid artery, optic nerve, maxillary nerve and vidian nerve. Injury to these structures gives rise to inevitable complications. Most of the complications are due to wide variation in anatomy of sphenoid sinus and its relations. This study is an attempt to know the percentage of variations in North Karnataka population, through cadaveric dissection and CT scan study.

Objectives –

To study variations in extent of pneumatization, termination of inter-sinus septa, accessory septae and its termination, dimensions of sphenoid sinus, presence of onodi cells and neuro-vascular relations of sphenoid sinus.

Material and methods –

Permission was taken from respective Heads of Department of Anatomy, ENT and Radiology and Principal, JNMC, Belgaum to conduct the study. Study was started with ethical clearance from Independent Ethics Committee.

All cadavers available in the Anatomy Department of Jawaharlal Nehru Medical College were included in the study. Selected patients and adults (age range - 18 to 85 years) from KLE's Dr. Prabhakar Kore Hospital and Research Center, Belgaum were included in the study. Consent was taken from all living subjects that were included in the study.

Endoscopic examination and dissection of sphenoid sinus was carried out in 30 cadavers (3 female and 27 male) using 0^0, 30^0, 70^0 rigid nasal endoscopes. Sections were then made in the sagittal plane to confirm the anatomical findings and to take the necessary measurements with millimeter strips.

Gross and endoscopic study was done in cadavers. Dimensions and relations of sphenoid sinus were noted and tabulated. Findings from CT scan study were tabulated separately.

Results –

In 20% of cadavers the sphenoid sinus was pre-sellar, in 14% it was sellar and in 66% it was post-sellar. Conchal type of sphenoid sinus was absent. Bony septa or crests were seen in 13 cadavers, out of which in 4 cadavers (32%) they were bilateral and in remaining 9 cadavers (69%) they were unilateral. The septa terminated on bone covering internal carotid artery (ICA) in 7 cadavers while in 2 cadavers they terminated on the bone covering optic nerve (ON). Dimensions of the sphenoid sinus were antero-posterior (2.5 ± 0.5 cm), transverse (2.4 ± 0.4 cm) and vertical (2.2 ± 0.6 cm). The sphenoid ostium was oval or rounded in 28 and 32 cases respectively. The average size of sphenoid sinus was 5.7 ml. In 14 cadavers we found right dominance and in 8 cadavers left dominance. In 22 cadavers inter-sinus septum terminated on sites other than normal position. In 8 cadavers it terminated over bone covering internal carotid artery and in 3 cadavers it terminated on bone covering optic nerve. In rest of the cadavers it terminated away from the midline. Carotid prominence was found in 15 sinuses and optic nerve bulge was found in 6 sinuses.

Our findings of CT scan study were as follows: Out of 60 sinuses, pre-sellar-8 (13.3%), sellar-14 (23.3%) and post-sellar-37 (61.6%) and in case of 1 subject, left side sinus was conchal. Pneumatization of greater wing of sphenoid was observed in 2 sinuses (2.2%), of pterygoid process it was in 4 sinuses (6.6%) and of anterior clinoid process it was in 2 sinuses (2.2%). We also found onodi cell in 1 sinus (1.4%). Accessory septae were observed in 11 sinuses (18.2%), single in 7 sinuses (11.6%) and multiple in 4 sinuses (6.6%). In 6 sinuses these septae terminated over lateral wall of sinuses (10%) while in 4 sinuses they terminated over bony wall covering internal carotid artery (6.6%) and in 1 sinus on bony wall covering optic nerve (1.4%). The mean, standard deviations of all dimensions for male and female subjects respectively were: right antero-posterior 2.7 ± 0.42 and 2.7 ± 0.53 cm, left antero-posterior 1.9 ± 0.76 and 2.7 ± 0.55 cm, right transverse 2.2 ± 0.53 and 2.1 ± 0.62 cm, left transverse 1.7 ± 0.56 and 2.1 ± 0.54 cm, right vertical 2.4 ± 0.33 and 2.3 ± 0.43 cm, left vertical 2.1 ± 0.61 and 2.2 ± 0.43 cm. We found statistically significant correlation for right antero-posterior dimension. Right dominance was observed in 20 persons while left dominance in 10 persons. Protrusion of ICA was observed in 9 sinuses (15%). Protrusion of optic nerve was observed in 2 sinuses (33%). Protrusion of maxillary nerve and vidian nerve were observed in 3 sinuses (5%). Dehiscent bony wall was not observed in any sinus. Onodi cell was observed in 1 sinus (13%).

Endoscopic findings in live patients (18 male and 7 female) were: in 14 patients sphenoid ostium was round and in 11 patients it was oval. Accessory septa were observed in 16 patients (64%). In 3 patients (12%) accessory septa was inserted into the bony wall covering of the carotid arteries and only in 1 patient it inserted into the bony wall

covering of the optic nerve. Optic nerve bulge was observed in 6 patients (24%). Bony wall covering optic nerve was intact in all patients. Internal carotid artery bulge was observed in 8 patients (32%). Dehiscent bony wall was observed in 2 patients (8%).

Conclusion –

The present study was done to know the gross anatomy of sphenoid sinus and its relations. Surgeries over sphenoid sinus and pituitary gland can cause iatrogenic injuries to important structures and at times fatal complications. With the advent of Endoscopes and newer imaging techniques, surgeries over sphenoid are now safer. Sphenoid sinus shows various types of pneumatization, and when pneumatization spreads outside the body of sphenoid sinus it creates various recesses. These place the sinus in close proximity to important neurovascular structures that are present around the sinus.

Newer techniques are emerging for safety of patients due to complex and highly variable anatomy of the sphenoid sinus. Now intra-operative fluoroscopic imaging or intra-operative navigational devices are used to confirm surgical landmarks making these techniques very safe.

Key words –

Sphenoid sinus; endoscopy; pneumatization.

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INTRODUCTION

Paranasal air sinuses are mucous lined air filled cavities present in the skull. These sinuses are named according to bone in which they are present like frontal, ethmoid, maxillary, sphenoid. During last three decades, sinuses have got importance because of Functional Endoscopic Sinus Surgery (FESS). Computerized tomography (CT) is most precise imaging technique to demonstrate paranasal air sinuses.[1] CT screening of paranasal sinuses (PNS) has the advantages of showing bony details along with good soft tissue outlines.[2] Axial and coronal views may be useful for delineating the anatomical landmarks of the sinonasal cavity, but coronal CT scan provides most of the information required for an endoscopic clearance.[3]

Currently endoscopic endonasal surgery is a valuable and safe procedure that is routinely performed in the treatment of chronic sinusitis.[4] Inadequate understanding of these relationships undoubtedly increases the possibility of serious and occasionally fatal iatrogenic mishaps.[5]

Out of these sinuses, sphenoid air sinus is most inaccessible paranasal air sinus. It is also bordered by more vital structures than any other sinus. In recent years, this air sinus has got importance because of trans-sphenoidal approach to the pituitary gland.[5] Anatomical landmarks vary from patient to patient and are dependent upon different degrees of pneumatizaton of the paranasal sinuses.[6] Anthropological differences are important, e.g. white patients have larger nasal pyramids and smaller interpupillary distances in comparison to black and oriental patients.[7] Endoscopic endonasal approach

to the sella turcica offers a valuable and efficient procedure for removing pituitary adenomas.[8] It gives an outstanding visualisation and is a safe, straight-forward approach to sphenoid sinus.[8] Endoscopes offer improved visualization, angled view, and a wider panoramic perspective of the important anatomical relationships of the sphenoid air sinus and the sella turcica.[9]

Sphenoidal air sinus has complex relations and its diseases may, and usually do, give rise to a wide variety of symptoms.[10] Sphenoid air sinuses are irregular cavities with pneumatization ranging from absent to extensive. Pneumatization occasionally extends into the vomer, palatine bone, ethmoid bones, occipital bone, anterior clinoid processes, the lesser wings, the greater wings, the pterygoid process and plates, posterior clinoid process, and the clivus.[11] According to the extent of pneumatization, the bone covering the carotid arteries, optic nerves, maxillary nerves and vidian nerves can be thin or even absent, making these structures susceptible to iatrogenic injury.[12] That is why most of the complications of sphenoid sinus surgery are either neurological, (e.g. injury to optic nerve and cranial nerves III, IV, V_1 and V_2, trauma to optic chiasma) or vascular complications (like haemorrhage from internal carotid artery, cavernous sinus plexus). These complications are due to wide variation in relations of optic nerve and internal carotid artery to the sphenoid air sinus.

The different routes to the sella: trans-ethmoid, trans-nasal, trans-septal routes whether microscopic or endoscopic, ultimately pass through the sphenoid sinus to reach the sella. Therefore, the anatomical variations of the sphenoid sinus have major impact on the surgical access and the possibility of complications.[8] Knowing the details of the

anatomy of the sphenoid sinus and the extent of pneumatization can guide the surgeons through difficult corners of the approach. Actually, the demands of modern surgery, that aim more and more at functional preservation and restoration, have recently prompted a revival of anatomic investigation in this field.[13]

The variability in the anatomy of the sphenoid sinus is well documented. A comprehensive knowledge of the variable regional anatomy of the sphenid sinus will undoubtedly reduce the surgical complications associated with trans-sphenoidal and FESS.[14]

The present study is an attempt to describe the anatomy of sphenoid air sinus by using various parameters in cadavers and in adults of North Karnataka. By this study we will come to know the variations and its percentage in North Karnataka population and surgeons can use this knowledge during sphenoid sinus surgery.

ANATOMY OF SPHENOID BONE

The sphenoid bone is an unpaired pneumatic irregular bone which closes off the back of the nasal cavity and separates it from the anterior and middle cranial fossae.

The sphenoid bone (Figure No. 2) consists of a central body, pair of greater and lesser wings and pterygoid processes. This bone resembles a bat with outstretched wings if seen from front.

<u>Body</u> - It is central portion of the bone which is pneumatized by the two sphenoid sinuses, separated by a median partition. The body presents six surfaces - superior, inferior, anterior, posterior and two lateral surfaces.

<u>Superior surface</u> - presents following features from the front backwards:

1. Ethmoidal spine - triangular projection that articulates with cribriform plate of ethmoid bone.

2. Jugum sphenoidale - is a flattened plate of bone on which rests gyrus rectus of the frontal lobe and olfactory tract.

3. Sulcus chiasmaticus - anterior part of optic chiasma lies above this sulcus.

4. Tuberculum sellae - it is the posterior limit of sulcus chiasmaticus, and gives attachment to the diaphragma sellae. On each side lies the middle clinoid process, which is connected to anterior clinoid process by carotido-clinoid ligament. The carotido-clinoid foramen transmits upturned course of internal carotid artery. Occasionally this ligament gets ossified.

5. Hypophyseal fossa - contains pituitary gland and its floor is related to sphenoid sinuses.

6. Dorsum sellae – plate-like projection, presents posterior clinoid processes, gives attachment to the tentorium cerebelli, and is connected with anterior clinoid processes by interclinoid ligament. Below the posterior clinoid process, lateral margin of dorsum sellae presents a petrosal process which is connected to the tip of petrous

temporal bone by petrosphenoid ligament. Inferiorly this ligament is related to abducent nerve, which appears in the cavernous sinus after piercing dura mater.

Inferior surface - presents three features: sphenoidal rostrum, pairs of sphenoidal conchae and vaginal processes.

1. Sphenoidal rostrum – projects downward as a ridge and articulates with vomer.
2. Lower horizontal part of each sphenoidal concha articulates with the upper surface of the alae of vomer.
3. The vaginal processes are narrow triangular shelves arising from base of each medial pterygoid plate. Vomero-vaginal canal and palato-vaginal canal are present where it articulates with vomer and palatine bone respectively.

Anterior surface - presents three features: sphenoidal crest, a pair of sphenoidal conchae and articular rough area involving each concha.

1. Sphenoidal crest - vertical median ridge, articulates with the perpendicular plate of ethmoid bone.
2. Upper vertical part of sphenoidal conchae completes the anterior surface of the body. Sphenoid sinus communicates with the spheno-ethmoid recess of the superior meatus of nasal cavity through sphenoidal foramen present on each concha.
3. Above and lateral to sphenoidal foramen, triangular rough area articulates with the labyrinth of ethmoid and orbital process of palatine bones.

Posterior surface - forms primary cartilagenous joint with basi-occiput.

Lateral surface - each lateral surface joins with greater wing laterally and pterygoid process inferiorly. Carotid sulcus is present above the root of greater wing for internal carotid artery; it is also related to cavernous sinus and structures within the sinus.

Greater wings - these are strong curved plates from the side of the body and present three surfaces - cerebral, lateral and orbital; two borders - posterior and squamous; a tip and spine of sphenoid.

Cerebral surface - forms part of floor of middle cranial fossa and accommodates the temporal lobe. Some foramina present from the front backwards - foramen rotundum, foramen ovale, foramen spinosum, canaliculus innominatus and emissary sphenoidal foramen.

Lateral surface - divided into upper and lower areas by horizontal infra-temporal crest. Upper area forms part of temporal fossa and gives origin to temporalis muscle and lower area forms the roof of infra-temporal fossa and gives origin to lateral pterygoid muscle.

Orbital surface - forms the lateral wall of the orbit, its upper and lateral margins articulate with frontal and zygomatic bone respectively. Lower margin forms posterolateral boundary of inferior orbital fissure. The medial margin forms the inferolateral boundary of superior orbital fissure. Common tendinous ring is attached to the tubercle of the medial margin.

Posterior border - is non-articular in the medial part and articular in the lateral part. The medial part forms the anterior boundary of foramen lacerum while lateral part articulates with petrous temporal bone. Sulcus tubae is formed along the line of articulation in the exterior of the skull in which cartilagenous part of auditory tube lies.

Squamous border - articulates with squamous part of temporal bone.

The tip of greater wing articulates with parietal bone at the pterion while triangular rough area articulates with the frontal bone.

Spine of the sphenoid - small pointed process projecting from the junction of posterior and squamous borders of greater wing. It gives attachment to three ligaments: spheno-mandibular, anterior ligament of malleus and pterygospinous; two muscles: tensor veli palatini and tensor tympani.

Lesser wings - each wing is a triangular plate projecting from the side of the body and connected to it by anterior and posterior roots, which enclose the optic canal between them and the sphenoidal body. Lesser wing presents anterior and posterior borders, and, upper and lower surfaces.

Anterior border articulates with the frontal bone, while the posterior border forms the junction between anterior and middle cranial fossae. The spheno-parietal sinus lies along the undersurface of the posterior border. Anterior clinoid process is a projection seen at the medial end of each posterior border.

Upper surface of lesser wing forms part of floor of anterior cranial fossa and lower surface forms posterior part of the roof of orbit and presents the opening of optic canal.

Superior orbital fissure is retort-shaped cleft between greater and lesser wings.

Pterygoid processes - these are downward projections from the junction of the root of greater wing and the body. Each process has medial and lateral pterygoid plates enclosing pterygoid fossa between them.

Both lateral and medial pterygoid plates present two borders: anterior and posterior; and two surfaces: lateral and medial.

OSSIFICATION- The tuberculum sellae divides the bone into pre- and post-sphenoid parts; both fuse in 7th or 8th month of intrauterine life. Pre-sphenoid part includes anterior part of the body and lesser wings and ossifies from six centers in cartilage; one for each lesser wing, two centers for anterior part of the body and one for each sphenoidal concha. Post-sphenoid part ossifies from eight centers; one for each greater wing, two centers for the posterior part of the body, one for each medial pterygoid plate and one for each lingula.

ANATOMY OF THE SPHENOID SINUSES

These are paired sinuses located in the body of the sphenoid bone, which are the most posteriorly located paranasal sinuses. These are divided asymmetrically by an inter-sinus septum. Their average measurements are:

Vertical - 2 cm

Transverse - 1.5 cm

Antero-posterior - 2 cm

Capacity (average) - 7.5 ml

Extent - posteriorly, it may extend upto anterior margin of foramen magnum; anteriorly, it may go upto roof of the orbit; and laterally upto the pterygoid canal.

Relations – (Figure No. 1) Sphenoid sinus is superiorly related to optic chiasma and hypophysis cerebri. The optic nerve also has a significant relationship to the sphenoid sinus. As the optic nerve travels within the optic canal, it passes over the antero-lateral region of the roof of sphenoid sinus.

Inferiorly, it is related to roof of the naso-pharynx.

Lateral to the sphenoid sinus lies the cavernous sinus. The close proximity of the sphenoid to the structures within the cavernous sinus accounts for the danger of acute sphenoiditis. Within the cavernous sinus lies the internal carotid artery as well as cranial nerves III, IV, V_I and V_2. These structures may lie adjacent to the sphenoid and cause indentations within the wall. The internal carotid artery can be observed indenting the posteroinferior surface of the lateral wall. (Figure No.10)

Posteriorly, it is related to pons and medulla oblongata separated by the basilar venous plexus.

Anteriorly, related to the spheno-ethmoid recess. (Figure No.6)

Communication: It opens into the spheno-ethmoid recess and thereafter into the superior meatus of the nose. (Figure No.17)

Varieties - According to Hamberger's classification there are three varieties of the sphenoid sinus:-

Sellar type: floor of sella turcica bulging into a well developed sinus.

Pre-sellar type: cancellous bone of the sphenoid extends from under the sella turcica to the anterior aspect of the floor.

Conchal type: sphenoid sinus is absent and entirely filled by cancellous bone (Figure No.13). This type is common in children below 12 years.

Onodi cells – (Figure No.14) These are posterosuperior ethmoidal air cells lying within sphenoid bone.

Blood supply - this is by posterior ethmoidal branch of the ophthalmic artery and nasal branch of the sphenopalatine artery.

Venous drainage - is done by posterior ethmoidal vein draining into the superior ophthalmic vein.

Lymphatic drainage - lymphatics drain into the retro-pharyngeal lymph nodes.

Nerve supply – sensory nerve supply arises from posterior ethmoidal nerves while parasympathetic secretomotor fibers are derived from orbital branches of the pterygopalatine ganglion.

Development – most of the sinuses are rudimentary or absent at birth, but they enlarge appreciably during eruption of permanent teeth and after puberty. The most posterior ethmoid cells grows into the sphenoid bone to form sphenoid sinus. Pneumatization begins at age 3 years and progresses rapidly between ages 5-7 years. Various degrees of pneumatization exist. Although the sphenoid most commonly is fully pneumatized, the structure can be partially aerated or filled completely with bone. Pneumatization may also occur in the bones adjacent to the sinus, such as the greater wing of the sphenoid bone or the vomer or palatine bones. (Figure No. 15)

OBJECTIVES

1. Endoscopically to study shape of sphenoid ostium and important anatomical features of sphenoid sinus such as pattern of pneumatization, inter-sinus septa and its termination, presence of onodi cells and presence of accessory septae. Relation of sphenoid sinus to internal carotid artery, optic nerve, maxillary nerve, vidian nerve and dehiscence or protrusion of these structures.

2. To confirm these endoscopic findings in cadavers after taking sections in the sagittal plane and to take necessary measurements of sphenoid sinus.

3. On CT scans to study the extent of pneumatization, dimensions of sphenoid sinus, presence of inter-sinus septa and its termination, presence of accessory septae and its termination, sphenoid dominance and relations of neuro-vascular structures.

REVIEW OF LITERATURE

History of sphenoid sinus –

Dr. Berg first described sphenoid sinus mucocele in 1889. Since then, a variety of surgical techniques have been used to approach the sphenoid sinus. Intra-cranial, septo-plastic, antral, external spheno-ethmoid and extensive intra-nasal technique have been described.[8] First systematic and detailed work documenting endoscopic findings was published in English by Messerklinger.[18] Messerklinger introduced the concept of functional endoscopic sinus surgery based on his endoscopic observation and documentation of anatomy and pathology in the middle meatal area.[6] According to Darf, the first attempt at nasal and sinus endoscopy was performed by Hirschmann in 1901 using a modified cystoscope.[19]

Horsley removed the first pituitary adenoma through a bi-frontal craniotomy approach in 1889.[20] The first intranasal trans-sphenoid approach was developed by Schloffer in 1907. Von Eiselberg, Cushing, Halstead and Hirsch modified this technique. Trans-sphenoidal hypophysectomy was first introduced in 1987 and since then endoscopic anatomy of sphenoid sinus gained importance.

The anatomy of sphenoid sinus was described by Ridpath (1947), J. C. Peele (1957), Dobromylsky & Scherbatov (1966), Davs & Coupland (1967), Simpson et al. (1967), Montgomery (1972), Ballenger (1977) and S. Elwany et al. (1983).

S. Elwany et al.[10] (1983) studied the anatomy of sphenoid sinus and its surgical application. They focused on relationships of the sella turcica to the sphenoid sinuses. In

their study, they examined 100 (50 males & 50 females) radiographs using various views. They measured dimensions of sphenoid sinuses in radiographs. They also did radiological examination of dried skull (100). Some findings were studied in sagittal section of dried skulls, like extent of pneumatization of the sinus, inter-sinus septa and relations of sphenoid sinuses. Fifty cadaveric dissections in sagittal and coronal planes were also done. They found 146 pre-sellar sinuses and 354 post-sellar type of sinuses. Average dimensions were: antero-posterior (1.6cm & 3.1cm), transverse (1.2cm & 1.9cm), vertical (1.4cm & 2.6cm); average size was between 9.1-7.9ml.

S. Elwany et al.[5] (1999) studied endoscopic anatomy of sphenoid sinus in cadaver heads (186 sphenoid sinuses) using endoscopic dissection as well as sagittal sections for viewing ostium of sphenoid sinus; its location & shape. They found round ostia in 133 sinuses with mean diameter of 2.8 mm while in the remaining it was oval. They also studied presence of accessory septa and their termination on important neurovascular structures. They found bony septa in 128 sinuses. In 89 sinuses they were unilateral and in the remaining (39 sinuses) they were bilateral. These septae ended over bony covering of internal carotid artery in 24 sinuses and into bony covering of optic nerve in 11 sinuses. Impression of the carotid canal was found in 167 sinuses while dehiscence in bony covering of carotid artery was seen in 9 sinuses. Optic nerve bulge was seen in 54 sinuses and dehiscence in bony covering of optic nerve was absent. Maxillary nerve bulge was present in 24 sinuses, vidian nerve bulge in 14 sinuses. Onodi cells were found in 7 cadavers. In 5 cadavers they were bilateral. In two cadavers, optic nerve made a clear impression but with intact bony wall. They noted various recesses like infra-optic (in 78

cases), inferolateral (in 59 cases), pterygoid (in 29 cases) and posterior clinoid (in 11 cases).

Deepika Sareen et al.[21] (2005) studied 20 cadaveric skulls in different sections. They found 15 sinuses post-sellar and 5 sinuses pre-sellar while 16 sinuses showed multiple septation and 4 sinuses had a single septum. Dehiscent internal carotid artery was found in 1 skull.

Dharambir Sethi et al.[22] (1995) studied endoscopic anatomy of the sphenoid sinus and sella turcica in 30 cadavers. Interior of sphenoid sinuses was studied with 0^0, 30^0, 70^0 endoscopes. Pattern of pneumatization, shape & size of ostium, inter-sinus septae, sella turcica, internal carotid arteries, optic nerve and optic chiasma were studied. They found: 8 pre-sellar, 22 post-sellar; 28 round ostia, 24 oval ostia; onodi cell in 3 sinuses. Dehiscent optic nerve was observed in 2 sinuses.

Hewaidi G. H. & Omami G. M.[3] (2008) studied paranasal CT scans of 300 Libian patients, age ranging between 18-82 years. Contiguous slices of 2 mm thickness from anterior to posterior wall of sphenoid sinus centered to the nasal cavity & paranasal sinuses were studied. All the parameters related to sphenoid sinus were studied. Axial & coronal views were used for the study. Comparison between coronal and axial CT scans to determine variations of paranasal sinuses was done.

Ossama Hamid et al.[23] studied 296 magnetic resonance imaging (MRI) and CT scans of patients of pituitary adenoma. Pre-operative & post-operative axial & coronal CT scans were used to study anatomical variations of sphenoid sinus. Impact of these variations on surgical approach and surgical complications were studied.

Robert M. & Galdino MD [24] (1998) and G. Tetani[13] (1987) studied paranasal CT scans from surgeon's point of view. They studied anatomical variations of sphenoid sinus and relation of neurovascular structures. According to the variations they came across, they suggested precautions to be taken by surgeons while approaching sphenoid sinus during surgical procedures.

Harvey Tucker et al.[25] (1982), Peter Koltani et al.[26] (1985), James Stankiewicz[8] (1989), Roger Jankowski[4] (1992), W. R. Wilson et al.[7], Harsha V. Gopal [20] (2000), Heinz Stammberger[27] (1990) studied various surgical approaches in diseases of sphenoid sinus and impact of the variations on approaches. Possibilities of complications while using these approaches were also studied.

Diseases & surgical complications of sphenoid sinus were studied by William Gibson[28] (1984).

Use of endoscopes in the repair of PNS cerebrospinal fluid (CSF) fistulas and in the diagnosis & treatment of CSF rhinorrhea was studied by Francis A Papay et al.[29]

Other studies on sphenoid sinus surgery, its complications and management of complications were done by Carl & Kavin[30] (2010) and Anthony Maniglia[31] (1988).

Diseases Of Sphenoid Sinus

SPHENOID SINUSITIS –

Sinusitis is defined as an inflammatory response involving mucous membranes of the nasal cavity and paranasal sinuses, fluids within these cavities and/or bone. Acute sphenoid sinusitis is relatively uncommon; comparatively, chronic sphenoid sinusitis is more common. The condition is classified as acute if it persists for 4 weeks or lesser. In contrast, a sub-acute infection is defined as that lasting from 4-12 weeks, and a chronic infection persists for more than 12 weeks. When this inflammatory response occurs in the sphenoid sinus, the result is sphenoid sinusitis or sphenoiditis. The disease may be limited to the sphenoid sinus or, more commonly, may involve multiple sinuses or pan-sinusitis.

Frequency :

Sphenoid sinusitis often occurs in the context of pan-sinusitis. In the pre-antibiotic era, Teed reported an incidence of sphenoid involvement of 33% in patients with pan-sinusitis[31] A study by Weisberger and Dedo (1977) suggested that in the antibiotic era, incidence decreased to 8%. Isolated sphenoid sinusitis is much less common. Lew reported a 2.7% incidence in patients hospitalized for sinusitis in a 12-year period.[23]

Etiology :

The microbiology of acute sphenoid sinusitis differs from that of uncomplicated maxillary sinusitis. Gram-positive organisms predominate, with *Staphylococcus aureus* being most common, followed by *S. pneumoniae*. Chronic sphenoid sinusitis can be

caused by both gram-negative and gram-positive organisms, anaerobes, and mixed flora, which are more common. Fungal disease is common in the context of a patient who is immuno-compromised.

Presentation :

Patients with acute sphenoid sinusitis often present with vague non-localizing symptoms. Headache is the most common symptom; vertex headache is classic, the pain also can be retro-orbital, parieto-occipital, or frontal. Fever and purulent rhinorrhea are often noted, and hypoaesthesia of the trigeminal nerve may be present. Neurologic and ophthalmologic findings suggest impending complications. Decreased mental status, lethargy, and seizures point to intracranial extension or meningitis.

Ophthalmologic findings may include abducent nerve palsy or hypoaesthesia of V_1 and/or V_2. Chemosis, proptosis, ptosis, diplopia, or decreased visual acuity and ophthalmoplegia may be noted.[26]

Diagnosis :

- CT scan
    - In the workup of a patient with suggested sphenoid sinusitis, imaging studies are the mainstay of diagnosis. CT scan establishes the presence of sphenoid disease and provides information on bony erosion. An air-fluid level is usually observed in acute disease, while complete opacification is more common in chronic disease. A globular opacity filling the cavity is

likely to be a retention cyst or polyp; however, further studies are needed to rule out a rare encephalocele or aneurysm.

- In the acute sinusitis, a CT scan establishes the anatomy of the sphenoid, including the size of the cavity and the inter-sinus septum. The presence of pan-sinusitis can also be determined. The internal carotid artery, pituitary gland and optic nerve are also identified.

- MRI
    - MRI is useful in evaluating the relationship of the sphenoid to its surrounding structures. Although CT scan is useful in showing bony erosion, MRI is better for imaging of soft tissues. Several CT scan findings require further workup with MRI. Bony erosion requires an MRI to differentiate mucocele from tumors. An image with low density on T1 images and high density on T2 is characteristic of a mucocele. Tumors tend to show intermediate density in T1 and T2 images. Fungal sinusitis can be identified by signal voids within the sinus. A mixed signal pattern, in contrast, is typical of fibro-osseous disorders. Any extra-sinus extension in conjunction with bony erosion is likely to be a malignancy. Partial opacification of the sphenoid may occasionally represent an internal carotid artery aneurysm or encephalocele.
    - In the setting of acute sphenoid sinusitis, MRI is valuable in evaluating patients with neurologic or visual complaints for evidence of complications. The structures surrounding the sphenoid (e.g. dura, optic

nerve, cavernous sinus) are demonstrated. Cavernous sinus thrombosis, in particular, can be identified.

- Magnetic resonance angiography (MRA) can be used to confirm the diagnosis of cavernous sinus thrombosis.

Treament - Medical Therapy :

- Initial treatment of a patient with uncomplicated sphenoiditis begins with medical therapy. Once the diagnosis is made, broad-spectrum antibiotics along with topical and systemic decongestants are given. Medical treatment is tried for 24 hours. If the patient does not improve over this time course, surgical therapy is scheduled; if the patient has evidence of complications, urgent surgical decompression is done.

Surgical Therapy

- The goals of surgery are to identify the sphenoid ostium, enlarge it, and establish drainage. Diseased mucosa is removed and cultures obtained.
- The classic approaches include trans-septal, trans-antral, intra-nasal, and external, but endoscopic surgery is now commonly used.

Pre-operative Investigation:

Pre-operatively, imaging studies are reviewed to determine bony anatomy and areas of disease. The approach to the sphenoid sinus is decided based on associated disease as well as surgeon preference.

<u>Intra-operative Details</u> :

- When operating on the sphenoid sinus, the relationship of the sphenoid sinus to the surrounding structures is of paramount importance. The anterior wall of the sphenoid is approximately 7 cm from the anterior nasal spine. The distance to the posterior sphenoid wall is approximated by measuring the distance to the posterior nasopharynx which is about 9 cm. The internal carotid artery and optic nerve may be observed indenting the lateral walls of the sphenoid sinus. The carotid artery was dehiscent in 4% of patients and covered with only a thin bony covering in 71% of patients[26]. The optic nerve was found in the supero-lateral aspect of the sinus, also dehiscent in 4% of patients[18]. A margin of safety can be obtained by staying medial and inferior while opening and exploring the sphenoid.
- Many approaches to the sphenoid have been described. Among the earliest was the trans-septal trans-sphenoidal approach, described by Cushing and Hirsh (1910) in the context of pituitary tumor resection.[26] This approach was repopularized by Hardy in the 1950s and is still in use.
- The trans-antral approach has also been used for sphenoid disease. The middle turbinate is used as a guide to the sphenoid ostium. The ostium is found superior and medial to the posterior aspect of the middle turbinate. Then, the anterior sphenoid wall is opened.
- Another classic approach is the intra-nasal approach. The posterior ethmoid cells are removed to create a common cavity between the sphenoid sinus and the

posterior ethmoid. External spheno-ethmoidectomy is used infrequently because an external incision is needed.

- The advent of endoscopic sinus surgery has dramatically changed the approach to sphenoid disease. Endoscopic approaches provide excellent visualization of the anatomy and disease process. Advantages include reduced operating time, minimal blood loss, and decreased morbidity compared to the classic techniques.
- If sinus disease involves both the sphenoid and the ethmoid sinuses, a trans-ethmoidal approach is taken. The middle turbinate is medialized to visualize the uncinate process. The uncinate is removed, and identified, and then the ethmoid bulla is opened. This is followed by an anterior and posterior ethmoidectomy. The sphenoid sinus is located medial and inferior to the posterior ethmoid air cells.
- If isolated sphenoid disease is present, a trans-nasal approach can be used. The middle turbinate is displaced laterally and the endoscope is passed along the septum until the superior turbinate is identified. The superior aspect of the superior turbinate is transected and removed. The sphenoid ostium is identified in the area between the remnant and the septum. The ostium is enlarged inferiorly. An endoscope can then be passed directly into the sphenoid sinus to evaluate the location of the carotid artery and optic nerve. With these structures identified, the ostium can be enlarged further. A diameter of 5-10 mm is advocated to reduce the likelihood of recurrent obstruction.
- Stankiewicz describes an alternate approach to isolated sphenoid disease.[8] He advocates fracturing the middle turbinate toward the septum. Incisions are made

in the antero-superior and postero-inferior portion of the middle turbinate and this tissue is removed.

- Post-operatively, the patient is monitored for complications of the sinus disease as well as the procedure.

Complications :

- Complications of acute sphenoid sinusitis relate to the vital structures that surround the sinus. Expansion into surrounding structures, local osteitis, or thrombophlebitis in draining vessels may cause complications. Orbital cellulitis, orbital abscess, and orbital fissure syndrome occur from extension towards the orbit; cavernous sinus thrombosis and blindness may occur. Meningitis, epidural and subdural abscess result from intracranial extension. Carotid artery thrombosis may also occur, although very infrequently. The close proximity of the sphenoid to the pituitary can lead, in some cases, to hypopituitarism.
- The sinus surgery itself has potential complications, again based on the vital structures that surround the sphenoid sinus. Intra-operative complications are predominantly vascular in nature and include persistent hemorrhage from the carotid artery, or, infrequently, the cavernous sinus. Retrobulbar hemorrhage with proptosis and visual compromise requires urgent ophthalmological consultation and lateral canthotomy. Persistent hemorrhage from the sphenoid or cavernous sinus may require angiography to localize and control bleeding.
- Postoperative complications may be nasal, neurologic, or vascular in nature. Long-term complications include cosmetic deformities; septal perforations may

occur and are predominantly related to approach. In the peri-operative state, epistaxis is also a risk. Neural structures, including the optic nerve or any structures running through the cavernous sinus, may be damaged during surgery. Cranial nerves that control extraocular movements (i.e. CN III, IV, VI) are at risk, as are the ophthalmic (i.e. V_1) and maxillary (i.e. V_2) divisions of CN V. Cerebrospinal fluid leak is possible if the roof of the sphenoid is violated. Hemorrhage from the internal carotid artery or cavernous sinus is a devastating complication that may occur intraoperatively or postoperatively. Any unexplained mental status changes or excessive bleeding need immediate evaluation.

- Outcome and prognosis for sphenoid sinusitis depend highly on early diagnosis. Lew concluded that treatment delay inevitably led to serious morbidity and mortality.[11] In his study, 9 out of 15 patients had a delay in treatment. Four patients died, and 4 had irreversible cranial nerve injury. Kibblewhite et al. came to similar conclusions.[9] In their study of 14 patients with acute sphenoid sinusitis, 57% of the patients had signs of neurologic or ophthalmologic complications, and 29% of the patients were left with permanent disabilities. A delay in diagnosis led to an 80% morbidity rate. The conclusion is that early diagnosis is essential. If properly treated, patients with acute sphenoid sinusitis can improve without complications.
- Controversies exist in several areas. Administration of broad-spectrum antibiotics is necessary. A drug that crosses the blood-brain barrier is considered if complications are present or seem likely. Antibiotics are adjusted to cultures when available. Use of steroids is generally not indicated.

- Acute sphenoid sinusitis can be a devastating disease if not diagnosed quickly. CT scans lead to earlier diagnosis and treatment. Endoscopic approaches to drainage are safe and effective. The combination of these 2 modalities should result in improved outcome and prognosis. Image guidance systems are being used more frequently in sinus surgery. The use of image guidance systems in diseases of the sphenoid is especially helpful and adds an extra dimension of safety to the procedure.

SPHENOID MUCOCELE -

- Mucoceles of the sphenoid sinus are rare. They represent 1% of all paranasal sinus mucoceles. Because of the close proximity with vital structures, early diagnosis and treatment of the disease is essential to prevent morbidity.
- A mucocele is an epithelial-lined mucous containing sac which is capable of expansion. Males and females are equally affected. Mucoceles are rare in the pediatric population because the sphenoid sinus completes its pneumatization at about 12 years of age.[21] The etiology of mucocele is not clear. Mechanical obstruction of sinus ostia from trauma, nasal polyposis, allergic rhinitis and chronic sinusitis are the most common causes of mucocele formation.
- Diagnosis of a mucocele is based on history, physical and imaging examinations. The sphenoid sinus is difficult to directly examine. Thus, CT scan and MRI examination of the paranasal sinuses are necessary. CT examination demonstrates the bony landmarks, anatomic variations of the paranasal sinuses and shows the enlargement of sphenoid sinus mucocele. MRI

examination reveals sphenoid sinus expansions in all directions.[23] The differential diagnosis include hypophyseal tumors, craniopharyngiomas, meningiomas, gliomas, and tumors of skull base.[21]

- The most commonly reported clinical manifestations are headache (89% of cases), decreased visual acuity (57%), oculomotor palsies (56%), and exophthalmos (25%). Some patients present with acute onset of significant visual loss. Sudden bilateral blindness has also been reported in the literature. [32]
- There are two mechanisms that explain the visual impairment in sphenoid sinus mucocele. A gradual loss of vision is caused by circulatory disorder of the optic nerve caused by the gradual pressure exerted by a sphenoid mucocele. A sudden onset of visual loss is the result of spread of infection or inflammation from the mucocele to the optic nerve.[33] The prognosis for the recovery of the visual loss is poor if the onset is sudden or if there is no light perception preoperatively .[32]
- An external surgical approach was often used for the management of sphenoid mucoceles before endoscopic surgery techniques became available. Marsupialization by partial removal of the anteroinferior walls of the mucocele using an endoscopic endo-nasal approach has been the primary surgical choice.[8] This approach prevents recurrences and complications. Prompt diagnosis of the disease can prevent development of serious mortality and morbidity.
- Sphenoid sinus mucoceles, even though rare, must be kept in mind in patients presenting with visual disturbances, proptosis and headache. Large sphenoid mucoceles can be managed by endoscopic sinus surgery with drainage through

the nasal cavity. This procedure can be performed on an out-patient basis with little patient morbidity. The patency of the surgical drainage can be periodically checked, and if necessary the sphenoid sinus cleaned, using the fibreoptic endoscope. Prompt investigation, diagnosis and early surgery are required to avoid permanent complications of the disease.

SINO-NASAL TUMORS

- Sinonasal malignancies (SNM) can grow to considerable size before presentation and aggressive therapy may be needed in areas close to the skull base, orbits, cranial nerves, and vital blood vessels.
- Although rare, sinonasal malignancies (SNM) can be lesions of immense importance. They produce few if any signs while the tumor is in its early stages. This problem is exacerbated by the fact that the initial manifestations (e.g. unilateral epistaxis, nasal obstruction) mimic signs and symptoms of many common but less serious conditions. Therefore, the patient and clinician often ignore or minimize the initial presentation of these tumors and treat early-stage malignancy as a benign sinonasal disorder.
- By the time ominous signs and symptoms (such as severe intractable headache, visual disturbance or cranial neuropathy) occur, the neoplasm is often advanced. The anatomy of the nasal cavity and paranasal sinuses cause these tumors to manifest in advanced stages and complicate their treatment. They are located adjacent to important structures such as the skull base, orbits, cranial nerves, and

vital vascular structures. The obvious morbidity and complications associated with surgical resection of such tumors can be severe.

- Treatment of sinonasal malignancies (SNM) is best accomplished through a multidisciplinary team. Optimally, this includes a head and neck oncologic surgeon, reconstructive surgeon, maxillofacial prosthodontist, radiation oncologist, medical oncologist, neuroradiologist, pathologist, and neurosurgeon.
- SNM are more common in Asia and Africa than in the United States. In parts of Asia, sinonasal malignancies (SNM) are the second most common head and neck cancers behind nasopharyngeal carcinomas. Men are affected 1.5 times more often than women, and age ranging from 45-85 years.
- Approximately 60-70% of sinonasal malignancies (SNM) occurs in the maxillary sinus and 20-30% occurs in the nasal cavity itself. An estimated 10-15% occurs in the ethmoid air cells (sinuses), with the remaining minority of neoplasms found in the frontal and sphenoid sinuses.
- Risk factors for sinonasal malignancies (SNM) have been extensively investigated. They are complicated, multifactorial, and somewhat controversial. The fact that squamous cell carcinoma (SCC) and adenocarcinoma in this area are associated with exposure to nickel dust, mustard gas, thorotrast, isopropyl oil, chromium, or dichlorodiethyl sulphide is well established. Wood dust exposure, in particular, is found to increase the risk of SCC 21 times and the risk of adenocarcinoma 874 times. Many of these products are found in the furniture-making industry, the leather industry, and the textile industry. A careful social and

employment history should be taken from all patients presenting with symptoms concerning sinonasal malignancies (SNM).[33]

- Viral infections and their relationship to malignancy is an interesting area that has not received sufficient investigation. Preliminary studies show that epidermal growth factor receptor (EGFR) and transforming growth factor-alpha (TGF-alpha) in elevated levels of expression may be associated with early events in inverting papilloma (IP) carcinogenesis. Human Papilloma Virus (HPV) and Epstein Barr Virus (EBV) infection may also be an early event in a multistep process of malignant transformation of inverting papilloma (IP).

Inverted papilloma

- Although inverted papilloma (IP) is a benign lesion in most cases, it can be a locally aggressive tumor with malignant potential.

Squamous cell carcinoma

- Squamous cell carcinoma (SCC) constitutes over 80% of all malignancies that arise in the nasal cavity and paranasal sinuses. Approximately 70% occurs in the maxillary sinus, 12% in the nasal cavity, and the rest in the nasal vestibule and other sinuses.
- Several carcinomas are often considered variants of squamous cell carcinoma of the nasal cavity and paranasal sinuses. These include verrucous carcinoma, basaloid squamous cell carcinoma, spindle cell carcinoma, and transitional or cylindrical cell carcinoma.

Adenoid cystic carcinoma

- Adenoid cystic carcinoma (ACC) is of salivary origin and is the second most common sinonasal malignancy, accounting for 10% of cases. Three histological subtypes are based on growth patterns: tubular, cribriform, and solid. These subtype distinctions are important because the solid form presents a much worse prognosis than either cribriform or tubular.

Adenocarcinoma and its variants

- Adenocarcinoma of the nasal cavity and paranasal sinuses is historically important and is associated with specific risk factors including exposure to wood dust, lacquers, and other organic compounds.
- Both low- and high-grade adenocarcinoma can cause obstructive symptoms, rhinorrhea, or epistaxis. Regardless of grade, local destruction of the orbits and skull base is frequently seen.

Malignant melanoma

- Malignant melanoma is a rare disorder of the nasal cavity and paranasal sinus mucosa. It accounts for less than 1% of all malignant melanomas and less than 4% of nasal malignancies.

Sinonasal neuroendocrine tumors

- Sinonasal neuroendocrine tumors are a unique and often confusing group of sinonasal malignancies (SNM) including esthesioneuroblastoma (ENB), sinonasal

undifferentiated carcinoma (SNUC), neuro-endocrine carcinoma (NEC), and small cell neuroendocrine carcinoma (SmCNC).

Esthesioneuroblastoma

- Esthesioneuroblastoma (ENB), frequently called olfactory neuro-blastoma, is an uncommon but frequently studied tumor of the sinonasal tract. It constitutes 3% of all endonasal tumors.
- ENB most commonly originates from olfactory cells near the cribriform plate.

Small cell neuroendocrine carcinoma

- Small cell neuroendocrine carcinoma (SmCNC), similar to oat-cell carcinoma of the lungs, is reported to arise in the nasal cavity and paranasal sinuses in patients ranging from age 26-77 years. The fact that the tumor is almost always in an advanced stage by the time it comes to attention reflects its aggressive nature. Several sinuses are nearly always involved. Cervical lymph nodes involvement and pulmonary metastases may also be present.

Verrucous carcinoma

- Verrucous carcinoma is a type of squamous carcinoma grossly characterized by a fungating appearance with complex papillary infoldings.

Lymphomas and related conditions

- This category of malignant neoplasia of the sinuses and nasal cavity is complicated, poorly understood, evolving, controversial, and extensive.

- In general, non-Hodgkin lymphomas are primarily found in patients in their 60s and 70s and manifest with symptoms of obstruction.
- The tumor is a destructive sinonasal lesion associated with obstructive symptoms, bone and soft-tissue destruction, and hemorrhage. It is strongly associated with the Epstein-Barr virus and is most common in Asia with a patient age at presentation of 13-80 years.

Salivary-type neoplasms

- Pleomorphic adenomas, mucoepidermoid carcinoma, and other salivary gland neoplasms may arise in the nasal cavity and paranasal sinuses.

Presentation

- Initial presenting symptoms include epistaxis, nasal obstruction, recurrent sinusitis, cranial neuropathy, sinus pain, facial paraesthesia, proptosis, diplopia, or an asymptomatic neck mass. Often, these mimic signs of conditions more common and less serious than malignant tumors of the sinuses. The patient often ignores early symptoms, or the clinician may minimize them, treating early-stage malignancies as infectious diseases. By the time ominous signs and symptoms (e.g. severe intractable headache, visual disturbances) occur, the neoplasms are advanced and require complex management.
- Benign growths from outside the sinonasal tract in adjacent areas may lead to aggressive signs and symptoms and require radical and destructive therapy. Meningiomas may grow into the sinuses, and orbital tumors may extend into adjacent paranasal sinuses. Even benign conditions, such as juvenile

angiofibromas or nasal gliomas, may lead to death if not recognized and appropriately treated.

Treatment

- Therapy of sinus and nasal cavity malignancy is often multimodal. Radiation therapy, surgery and chemotherapy are usually administered in combination. The location of the anatomic structures in question may make the outcome of surgery intolerable to some patients. These locations are adjacent and connected to the orbits, brain, skull base, hard palate, and the carotid sheath.

Tumors of sphenoid sinus-

- The sphenoid sinuses are a subset of the paranasal sinuses and can generally be thought of as the sinuses, or cavities deep behind the nose between the eyes. Sphenoid sinus cancer is a least common form of paranasal sinus cancer.

Risk Factors

- People who are exposed to mustard gas, isopropyl oils, volatile hydrocarbons, or metals like nickel and chromium (which occurs most commonly in the leather tanning, nickel mining and carpentry industries) have an increased risk of developing paranasal cancer including sphenoid sinus cancer. Chronic sinusitis may also increase the risk of developing the disease. Tobacco's role in the development of sphenoid sinus cancer is less clear.

Sphenoid sinus cancer is extremely rare. Depending on the type and stage of the tumors, sphenoid sinus cancers are usually treated with surgery and radiation, and in advanced cases chemotherapy. Tissues in the sphenoid sinuses are highly vascular and bleeding is one of the more common risks associated with surgery.

<u>Diagnosis & recent advances</u> – Image guided surgery has many advantages. First, it provides three-dimensional localization data about specific points in an operating field relative to a preoperative imaging study, such as CT or MRI. It also allows preoperative imaging review at the computer workstation as well as software-enabled surgical planning.

In 1940s Spiegel and Wycis described the use of a framed stereotactic surgical system, which used a variety of instrumentation for calibration. In 1976, Bergstrom and Greitz described the application of this frame of stereotactic surgery to CT scan in which they applied a fixation device to the patient's head which held a metal trajectory ring in place. In the mid-1980s, with the improvement in CT scan images and the advent of personal computers, this enabled computers to provide intraoperative information on the placement of the instrument tip without the need for a frame. It was not until 1994 that Anon described the first intraoperative guidance system for endoscopic sinus surgery. This system worked on a probe, which was used to localize the instrument in space. However, it was attached to a bulky arm with several joints to the computer system. This was used for multiple sinus procedures in the late 1990's.

This takes us to the present day and the current technology. Basically, there are four components which are necessary for an image guidance system:

- A data set in three dimensions, such as a CT or MRI scan;
- Computer to process that CT data and allow it to be used in an interactive fashion;
- A mechanism to register the data set to the patient, such as the use of a headset or other fiducial markers.
- A mechanism to calibrate the instrument, as those instruments are manipulated inside the surgical field, their movements can be traced and translated to the data imaging set.

PITUITARY GLAND

- The pituitary is an endocrine gland that is grossly reddish-grey in color. It lies in the sella turcica and is surrounded by several important structures. On sagittal view at the mid-sphenoid level we can see the pituitary gland lying in the sella. The cavernous sinus is also seen with all its contents, including cranial nerves III, IV, V_1 and V_2 divisions of the trigeminal nerve. The abducent nerve travels laterally with the internal carotid artery and is most susceptible to injury, whereas the oculomotor, trochlear and maxillary nerves are more lateral and thus less susceptible.

- Microscopically, pituitary gland consists of two types of cells – chromophobes (50%) & chromophils (50%).

- Chromophils are subdivided into acidophils (40%) & basophil cells (10%). Acidophills secrete growth hormone and prolactin while basophils secrete thyroid

stimulating hormone (TSH), follicle stimulating hormone (FSH), leutinizing hormone (LH) in females and interstitial cell stimulating hormone (ICSH) in males. Clinical presentation of pituitary gland tumors depends upon type of cells involved.

- Pituitary adenomas are divided into two categories. They can be secretory (hormonally active) or non-secretory (hormonally inactive). The hormonally inactive pituitary adenomas require surgery when they cause mass effect causing a hypo-pituitary event, vision changes, pituitary apoplexia (hemorrhage into the adenoma itself) or severe headaches. Hormonally active pituitary adenomas include prolactinomas which are first treated medically with a dopamine agonist such as bromocriptine. In acromegaly and Cushing's syndrome, surgery can be offered as primary therapy; however, there are several different medical therapies that can be used to treat these conditions, such as somatostatin analogs and octreotide for acromegaly. A macroadenoma, defined as tumor greater than 1cm in size compresses the optic chiasma. A microadenoma, defined as tumor less than 1cm in size is most often discovered due to its hormonal activity.

- Tumors of the hypophysis produce symptoms of two types :

    A. Pressure effects

    B. Endocrine dysfunction

A. Pressure effects-

1. Headache is due to stretching of dura mater secondary to enlarged sella turcica.

2. Nasal discharge is due to involvement of sphenoid sinus.
3. Upward growth involves optic chiasma causing bitemporal hemianopia.
4. Pressure on hypothalamus may cause obesity or Frohlich's syndrome due to involvement of satiety centre.
5. Pressure upon third ventricle results in increased intracranial pressure.

B. Endocrine disturbances-

1. Adenoma of acidophil cells produces gigantism before puberty and acromegaly in adults.
2. Basophil adenoma causes Cushing's syndrome.
3. Chromophobe adenoma leads to hypopituitarism.
4. Lesions of the posterior lobe produce diabetes insipidus.

In mid-1800s the function and pathology of pituitary gland were unknown. This honey-colored gland that hangs from the base of the brain was at first a fascination for both scientists and doctors alike.

The trans-cranial approach to the pituitary was born in 1889 with an Englishman, Sir Victor Horsely, who performed trans-frontal surgery to resect a pituitary adenoma. He went on to publish a total of 10 operations in 1906, reporting a mortality rate of 20% and Paul and Caton performed the trans-temporal approach.[23]

The trans-sphenoidal surgery was first proposed by Giordano, who was Chief of Surgery at the University of Venice. He based his proposal on anatomic studies; however, he was not willing to perform the surgeries for fear of risk of meningitis. So, Herman

Schloffer, from Insbrook Austria, became the first to document trans-sphenoidal pituitary surgery in 1907.

Dr. Kocher introduced submucosal resection of the septum and arrived at the sphenoid from the midline. Dr. Cushing in 1909 at John Hopkins University in Boston modified the Schloffer approach. Cushing incorporated Halstead's sublabial incision and Kocher's submucosal resection of the septum to perform a sublabial trans-septal trans-sphenoidal approach. Between 1930 and 1960's, the trans-sphenoidal hypophysectomy surgery was essentially abandoned. Oscar Hirsch was a proponent of the trans-sphenoidal hypophysectomy, and he performed his first surgery around the same time as Dr. Cushing. He performed a 5-staged procedure over the course of 5 weeks. Then, in 1937, he modified his surgery to a 1-stage procedure. Norman Dott introduced the blunted speculum. A Frenchman, Gerard Guiot learned the approach from Dott in 1956. He instituted the use of intra-operative fluoroscopy. Jules Hardy introduced the operating microscope and microscopic instrumentation. This changed the goal of surgery. Prior to this, a pituitary surgery aimed to debulk a compressive pituitary macroadenoma that was causing either vision changes or headaches. With the implementation of microscopic instruments, the surgeons were able to resect sub-centimeter secreting microadenomas as well. In 1992, Jankowski described a truly endoscopic trans-sphenoidal pituitary surgery.

The advantages of truly endoscopic pituitary surgery are numerous. There is reduced operative time, superior illumination and magnification, diminished intra-operative blood loss (reported in some studies), and enhanced differentiation between normal glandular tissue and tumor. There are less endonasal complications, reduced

hospital stays, better patient satisfaction, no requirement of post-operative nasal packing, and no risk for tooth numbness. There is also less risk for septal perforation without the submucosal bilateral dissection of the septum that is employed in the traditional approach.

The disadvantage of the surgery is that there is loss of binocular vision of the microscope; however, with the endoscope's ability to look around corners, it provides excellent surgical field visualization. And although it is considered to be 2-D, the endoscope becomes a 3-D picture in the mind of the surgeon. There is also a steep learning curve for this surgery, especially for neurosurgeons who do not routinely use the endoscopes.

Functional Endoscopic Sinus Surgery

Functional endoscopic sinus surgery is the primary approach used today for the surgical treatment of chronic sinusitis. The physical examination is an excellent adjunct to the history in diagnosing or excluding chronic sinusitis.

Endoscopic sinus surgery is most commonly performed for inflammatory and infectious sinus disease. The most common indications for endoscopic sinus surgery are as follows:

- Chronic sinusitis refractory to medical treatment
- Recurrent sinusitis
- Nasal polyposis
- Antrochoanal polyps

- Sinus mucoceles
- Excision of selected tumors
- Cerebrospinal fluid (CSF) leak closure
- Orbital decompression (eg, Graves ophthalmopathy)
- Optic nerve decompression
- Dacryocystorhinostomy (DCR)
- Choanal atresia repair
- Foreign body removal
- Epistaxis control

CSF leaks associated with CSF rhinorrhea can be managed endoscopically. A success rate of 80% has been reported in the literature with primary endoscopic attempts; success rates increase to 90% if revision endoscopic closures are included.

Endoscopic approaches may also be applied for ophthalmologic procedures, including orbital decompression, endoscopic DCR, and optic nerve decompression for traumatic indirect optic neuropathy.

<u>Contra-indication</u> -

Certain conditions may require an external approach for complete treatment of disease; these include intraorbital complications of acute sinusitis, such as orbital abscess or frontal osteomyelitis with Potts puffy tumor. A careful review of preoperative CT scans or MRI films helps to guide the surgeon.

Complications

1. Orbital complication: including orbital haemorrhage, abscess, damage to optic nerve.
2. Intra-cranial complication: including CSF leak, meningitis, brain abscess, intra-cranial haemorrhage.
3. Nasal complication: including adhesion formation, anosmia, hyposmia, injury to lacrimal duct.

Various orbital complications of FESS include:

a. Orbital hematoma
b. Blindness
c. Diplopia
d. Nasolacrimal duct injury
e. Subcutaneous emphysema

Spinal Fluid Leakage

Spinal fluid leakage is a complication in 2% of endoscopic sinus surgeries. If this complication occurs, surgeons are most often able to recognize this immediately and will place a graft or other sealant over the area.

Endoscopic Repair of Paranasal Sinus Cerebrospinal Fluid Fistulas

Enhanced illumination and magnified views enabled surgeons to accurately diagnose specifically the area of the paranasal sinus spinal fluid fistula after failure of previous conservative management. Trans-nasal endoscopy enables accurate placement of a myofascial patch to the regions of the dural tear which resulted in obliteration of the CSF leak.

MATERIAL AND METHODS

The present study consisted of gross and endoscopic examination of sphenoid sinus in cadavers, endoscopic study of sphenoid sinus in living subjects and CT scan study of sphenoid sinus in living subjects.

Permission was taken from respective Heads of Department of Anatomy, ENT and Radiology and Principal, JNMC, Belgaum to conduct the study. Study was started with ethical clearance from Independent Ethics Committee.

Duration of study : February 2009 to June 2010.

Type of study : Cross-sectional study.

Inclusion criteria : All cadavers available in the Anatomy Department of Jawaharlal Nehru Medical College were included in the study. Selected patients and adults (age range - 18 to 85 years) from KLE's Dr. Prabhakar Kore Hospital and Research Center, Belgaum were included in the study. Consent was taken from all living subjects that were included in the study.

Exclusion criteria : We excluded patients with previous history of sinus surgery. Cadavers with damaged sphenoid sinus or its relations were excluded from the study.

Method of collection of data : Endoscopic examination and dissection of sphenoid sinus was carried out in 30 cadavers (3 female and 27 male) using 0^0, 30^0, 70^0 rigid nasal endoscopes. In all cadavers, the ostium of the sinus was located and the sinus then entered trans-nasally through its anterior wall. All areas of the sphenoid sinus were

explored and pertinent findings were recorded. Sections were then made in the sagittal plane to confirm the anatomical findings and to take the necessary measurements with millimeter strips. The size of the sphenoid sinus was measured by drilling a hole in its roof, and the sinus was filled with fluid, using a syringe, after occluding the ostium of the sinus with dental wax. The volume of the fluid that completely filled the sinus was an indication of the size of the sinus.

Endoscopic examination of sphenoid sinus was done in 25 living persons (7 females and 18 males). As sphenoid sinus is surrounded by neurovascular structures only a few possible parameters were studied.

CT scans of 30 living subjects (16 female and 14 males) were taken in coronal, sagittal and axial planes. Contiguous slice CT technique was used with 2mm section thickness. In all CT scans, we studied the type and extent of pneumatization, protrusion or dehiscence of neurovascular structures, presence of accessory septa or crest and its attachment, termination of inter-sinus septa. We also took antero-posterior, transverse and vertical measurements of the sphenoid sinus.

Statistical analysis - Mean and standard deviation was calculated for each reading. P value was calculated for CT scan measurements. Unpaired ‘t’ test was used to calculate the P value.

RESULTS

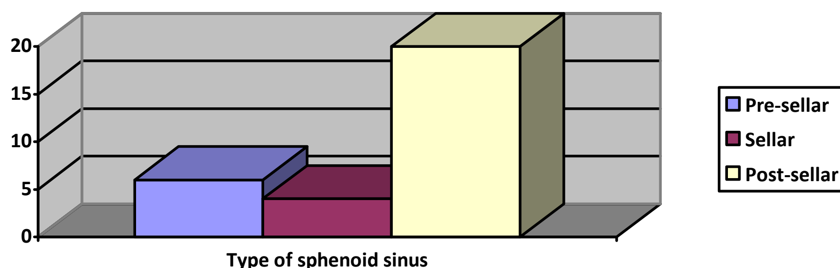
Endoscopic and gross anatomical findings in 30 cadavers: 27 male and 3 female; are as follows:

Types of sphenoid sinus – The sphenoid sinuses have been classified into conchal, pre-sellar, sellar and post-sellar types according to the extent of their posterior limits. In 20% of cadavers it was pre-sellar, in 14% it was sellar and in 66% it was post-sellar (Figure No.3). Conchal type of sphenoid sinus was absent.

Table No. 1: The types of sphenoid sinus

Type	No.	Percent
Pre-sellar	6	20%
Sellar	4	14%
Post-sellar	20	66%
Total	30	100%

Graph No. 1: Types of Sphenoid sinus

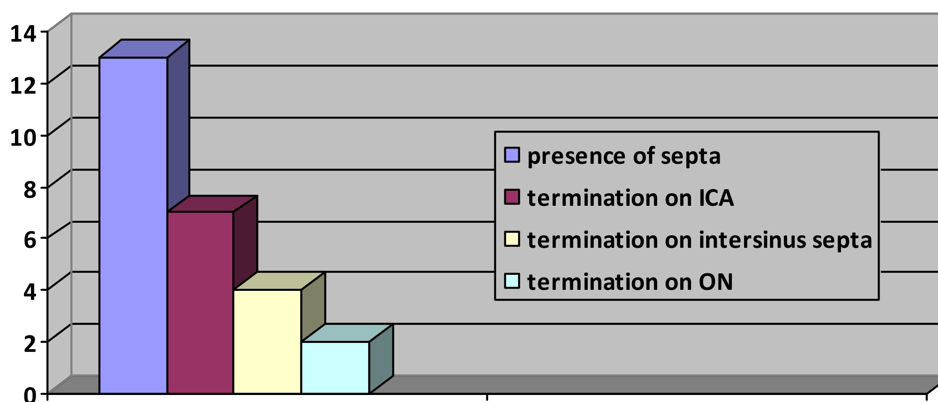


Accessory septa and crests – Bony septa or crests were seen in 13 cadavers, out of which in 4 cadavers (32%) they were bilateral and in remaining 9 cadavers (69%) they were unilateral. The septa terminated on bone covering internal carotid artery (ICA) in 7 cadavers while in 2 cadavers they terminated on the bone covering optic nerve (ON).

Table No. 2: Accessory septa and its termination

	No.	Percentage
Presence of septa	13	43%
Termination on ICA	7	23%
Termination on inter-sinus septa	4	13%
Termination on ON	2	6%

Graph No. 2: Accessory septa and its termination

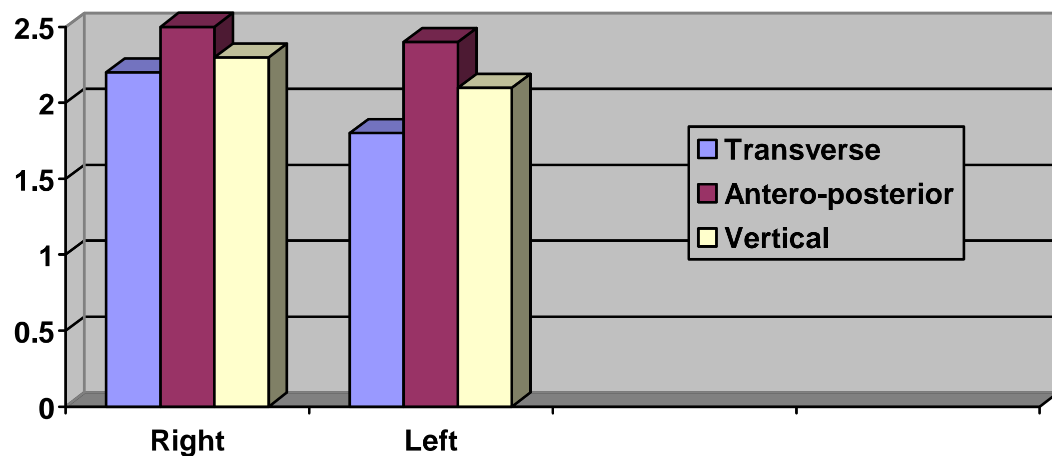


Dimensions of sphenoid sinus – Dimensions of the sphenoid sinus were as shown in the following table:

Table No. 3: Dimensions of sphenoid sinus

Dimension (cm)	**Right**	**Left**
	Mean ± SD	**Mean ± SD**
Transverse	2.2 ± 0.5	1.8 ± 0.4
Antero-posterior	2.5 ± 0.5	2.4 ± 0.6
Vertical	2.3 ± 0.6	2.1 ± 0.5

Graph No. 3: Dimensions of sphenoid sinus



<u>The sinus ostium</u> – The sphenoid sinus opens into the spheno-ethmoid recess near the midline. The ostia were oval or rounded.

Table No. 4: Shape of Ostium

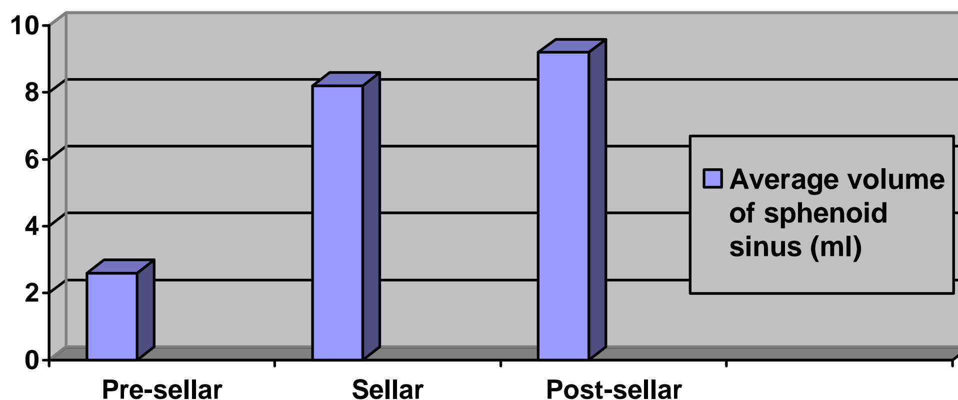
Shape of ostium	**N = 60**
Rounded	32
Oval	28

<u>Size of sphenoid sinus</u> – The average size of sphenoid sinus was as shown in Table No. 5.

Table No. 5: Volume of sphenoid sinus

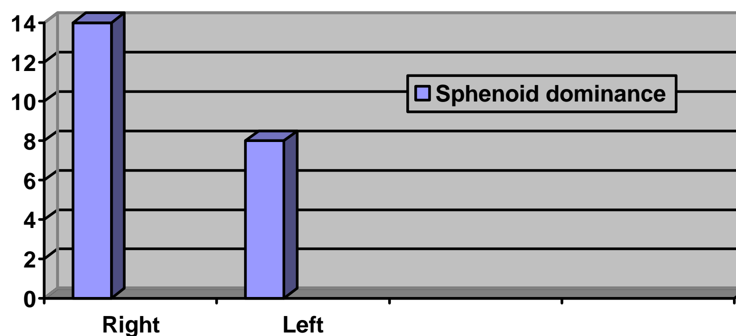
Type	**Average volume (ml)**
Pre-sellar	2.2
Sellar	8.2
Post-sellar	9.4

Graph No. 4: Average volume of sphenoid sinus



<u>Sphenoid dominance</u> – In 14 cadavers we found right dominance and in 8 cadavers left dominance (Figure No.7).

Graph No. 5: Sphenoid dominance



<u>Inter-sinus septa</u> - In 22 cadavers inter-sinus septum terminated at a site other than normal. In 8 cadavers it terminated over bone covering ICA and in 3 cadavers it terminated on bone covering ON. In rest of the cadavers it terminated away from the midline. Insertion of septum away from the midline gives rise to right or left dominance. (Figure Nos. 5 and 7)

Graph No. 6: Termination of Inter-sinus septa

<u>Relations of sphenoid sinus</u> – (Figure No.10) The cavernous part of the carotid artery frequently indents the lateral wall of the sinus producing a 'carotid prominence'. This bulge we found in 8 sinuses. The optic nerve is closely related to sphenoid sinus and it produces recognizable supero-lateral ridge. We found it identifiable in 3 sinuses.

<u>CT scan findings</u> :

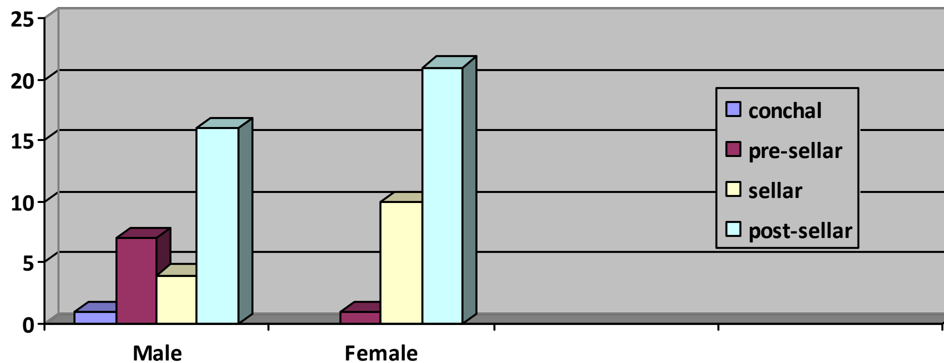
We studied 30 CT scans of sphenoid sinus (14 male and 16 female). Findings were as follows:

<u>Type of sphenoid sinus</u> – Out of 60 sinuses, pre-sellar (8), sellar (14) and post-sellar (37) and in 1 subject right side sinus was conchal (Figure No.13). Pnematization of greater wing of sphenoid was observed in 2 sinuses, that of pterygoid process in 4 sinuses (Figure No.15) and of anterior clinoid process in 2 sinuses. We also found onodi cell in 1 sinus (Figure No.14).

Table No. 6: Type of sphenoid sinus on CT scan examination

Type	Male	Female
Conchal	1	-
Pre-sellar	7	1
Sellar	4	10
Post-sellar	16	21

Graph No. 7: Type of sphenoid sinus on CT scan examination



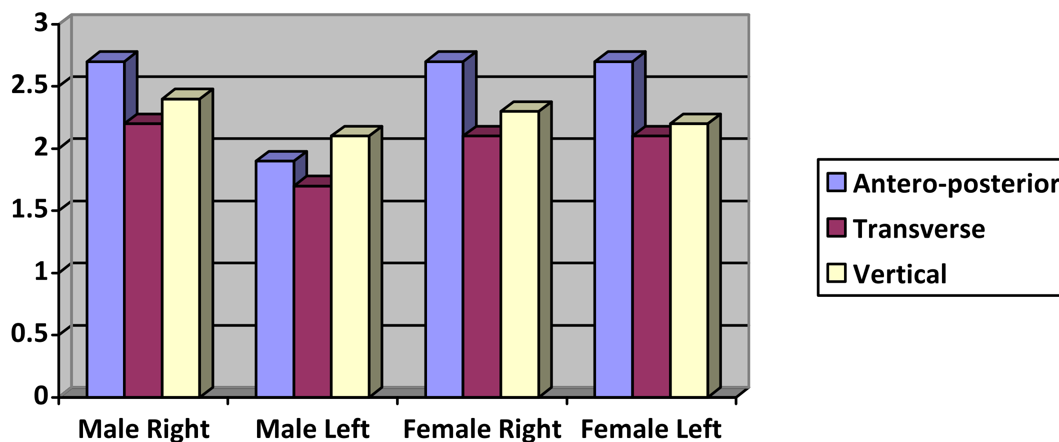
Accessory septa and its termination – Accessory septa were observed in 11 sinuses, single in 7 sinuses and multiple in 4 sinuses. In 6 sinuses these septa terminated over lateral wall of sinuses while in 4 sinuses they terminated over bony wall covering ICA (Figure No.16) and in 1 sinus on bony wall covering optic nerve.

<u>Dimensions of sphenoid sinus</u> – All dimensions were recorded and ‘p’ value calculated for each dimension. ‘p’ value was significant for right side AP dimension. The readings of different dimensions are shown in the master chart. The mean, standard deviations were noted and tabulated. Un-paired ‘t’ test was used to assess the significance of correlation.

Table No. 7: Dimensions of sphenoid sinus on CT scan examination

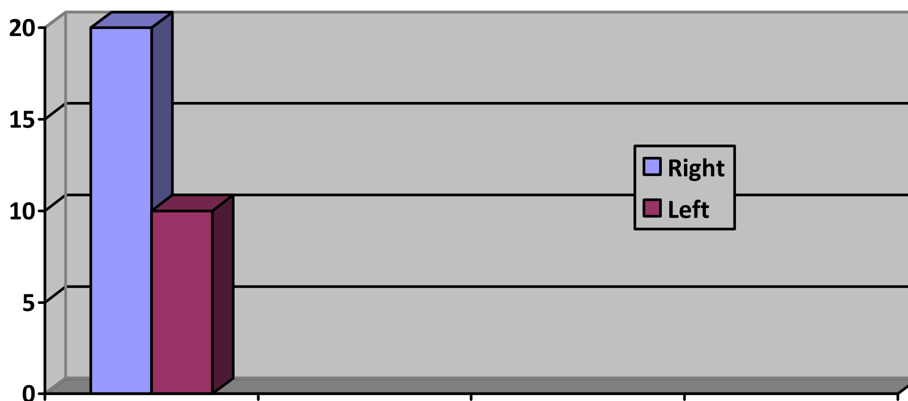
Dimension (cm)	**Male (Mean ± SD)**	**Female (Mean ± SD)**	**t value**	**DF**	**p value**
Antero-posterior Right	2.7 ± 0.42	2.7 ± 0.53	t = 0	DF = 28	p = 1
Antero-posterior Left	1.9 ± 0.76	2.7 ± 0.55	t = 3.332	DF = 27	p < 0.005
Transverse Right	2.2 ± 0.53	2.1 ± 0.62	t = 0.460	DF = 28	p > 0.05
Transverse Left	1.7 ± 0.56	2.1 ± 0.54	t = 1.989	DF = 27	p > 0.05
Vertical Right	2.4 ± 0.33	2.3 ± 0.43	t = 0.689	DF = 27	p > 0.05
Vertical Left	2.1 ± 0.61	2.2 ± 0.43	t = 0.524	DF = 28	p > 0.05

Graph No. 8: Dimensions of sphenoid sinus on CT scan examination



Sphenoid dominance – Right dominance was observed in 20 persons while left dominance in 10 persons.

Graph No. 9: Sphenoid dominance on CT scans



Relations of sphenoid sinus - Protrusion of ICA were observed in 9 sinuses. Protrusion of optic nerve was observed in 2 sinuses. Protrusion of maxillary nerve and vidian nerve were observed in 3 sinuses. Dehiscent bony wall was absent. Onodi cells were observed in 1 sinus.

Table No. 8: Relations of sphenoid sinus on CT scans

Protrusion of structures	No. of sinuses
ICA	9
ON	2
MN	3
VN	3
Onodi Cell	1

Graph No. 10: Relations of sphenoid sinus on CT scan

Endoscopic findings in live patients – Endoscopic findings were noted in 25 live patients (18 male and 7 female). As sphenoid sinus is surrounded by important neurovascular structures, we considered only a few parameters.

The shape of ostium – In 14 patients it was round and in 11 patients it was oval (Figure Nos. 8 and 9).

Accessory septa were observed in 16 patients (64%). In 3 patients (12%) accessory septa inserted into the bony wall covering of the carotid arteries and only in 1 patient it inserted into the bony wall covering of the optic nerve.

Optic nerve bulge was observed in 6 patients (24%). Bony wall covering optic nerve was intact in all patients. ICA bulge was observed in 8 patients (32%). Dehiscent bony wall was observed in 2 patients (8%).

DISCUSSION

The concept of normal sphenoid sinuses includes two symmetrical cavities with smooth walls and capacity of 5-7 ml, separated by a straight mid-line partition which does not encroach on any of the surrounding structures, and which in turn is not encroached upon by these elements.

There have been earlier reports on the microscopic anatomy and the neurovascular relationships of the sphenoid sinus and sella turcica (Renn and Rhoton 1975; Fuji et al. 1979; Lang 1989; Sethi et al.1995). These studies have required sagittal sectioning of cadaver heads or en bloc removal of the sella turcica to study the anatomical details.

<u>Gross and endoscopic findings in cadavers</u> –

S. Elwany et al.[2] (1983) studied the anatomy of sphenoid sinus and its surgical application. They focused on relationships of the sella turcica to the sphenoid sinuses. In their study, they examined 100 (50 males & 50 females) radiographs using various views. They measured dimensions of sphenoid sinuses in radiographs. They also did radiological examination of dried skulls (100). Some findings were studied in sagittal section of dried skulls, like extent of pneumatization of the sinus, inter-sinus septa and relations of sphenoid sinuses. Fifty cadaveric dissections in sagittal and coronal planes were also done. They found 146 pre-sellar sinuses and 354 post-sellar type of sinuses. Average dimensions were: antero-posterior (1.6cm & 3.1cm), transverse (1.2cm & 1.9cm), vertical (1.4cm & 2.6cm); average size was between 9.1-7.9ml.

S. Elwany et al.[1] (1999) studied endoscopic anatomy of sphenoid sinus in cadaver heads (186 sphenoid sinuses) using endoscopic dissection as well as sagittal sections for viewing ostium of sphenoid sinus; its location & shape. They found round ostia in 133 sinuses with mean diameter of 2.8 mm while in the remaining it was oval. They also studied presence of accessory septa and their termination on important neurovascular structures. They found bony septa in 128 sinuses. In 89 sinuses they were unilateral and in the remaining (39 sinuses) they were bilateral. These septae ended over bony covering of internal carotid artery in 24 sinuses and into bony covering of optic nerve in 11 sinuses. Impression of the carotid canal was found in 167 sinuses while dehiscence in bony covering of carotid artery was seen in 9 sinuses. Optic nerve bulge was seen in 54 sinuses and dehiscence in bony covering of optic nerve was absent. Maxillary nerve bulge was present in 24 sinuses and vidian nerve bulge in 14 sinuses. Onodi cells were found in 7 cadavers. In 5 cadavers they were bilateral. In two cadavers, optic nerve made a clear impression but with intact bony wall. They noted various recesses like infra-optic (in 78 cases), inferolateral (in 59 cases), pterygoid (in 29 cases) and posterior clinoid (in 11cases).

Deepika Sareen et al. (2005)[3] studied 20 cadaveric skulls in different sections. They found 15 sinuses post-sellar and 5 sinuses pre-sellar while 16 sinuses showed multiple septation and 4 sinuses had a single septum. Dehiscent internal carotid artery was found in 1 skull.

Dharambir Sethi et al. (1995)[4] studied endoscopic anatomy of the sphenoid sinus and sella turcica in 30 cadavers. Interior of sphenoid sinuses was studied with 0^0, 30^0, 70^0

endoscopes. Pattern of pneumatization, shape & size of ostium, inter-sinus septae, sella turcica, internal carotid arteries, optic nerve and optic chiasma were studied. They found: 8 pre-sellar, 22 post-sellar; 28 round ostia, 24 oval ostia; onodi cell in 3 sinuses. Dehiscent optic nerve was observed in 2 sinuses.

Shape of sphenoid ostium –

A pin head size sphenoid ostium was noted in 15 percent of the material studied by Lang (1989). Shape of sphenoid sinus ostium can be round or oval. S. Elwany et al. (1999) observed round ostia in 72 percent of material and oval in 28 percent of material. D. Sethi et al. (1995) found round ostia in 47 percent of cases and oval ostia in 40 percent of cases. In our study we found round ostia in 53 percent of cases and oval in 46 percent of cases in cadavers (Figure Nos. 8 and 9).

Type of sphenoid sinus –

The reasons for wide variation in the size of the sphenoid sinus are controversial. Pneumatization of the sphenoid bone is a function of the sub-epithelial layer of the sphenoid sinus mucosa. If due to local infection or malfunction of the endocrine glands, the pneumatizing function of this layer is impaired, then an abnormality of the sinus will develop on one or both sides.

In our cadaveric study, we found 67 percent post-sellar, 20 percent pre-sellar and 14 percent sellar type of pneumatization (Figure No.3). Conchal type of pneumatization was absent. S. Elwany et al. (1983) observed 30 percent pre-sellar, 71 percent post-sellar type of pneumatization. In another study done by D. Sethi et al. (1995) they observed pre-

sellar in 27 percent and post-sellar in 73 percent of sinuses. Sareen D. et al. (2005) found pre-sellar in 25 percent and post-sellar in 75 percent of sinuses. Renn and Rhoton (1975) also have same findings. They found pre-sellar in 32 percent and post-sellar in 68 percent of sinuses.

Sphenoid sinus of the post-sellar type offers optimum conditions for trans-sphenoid hypophysectomy, namely; roomy sinuses, thin anterior wall and floor of sella turcica[2]. On the other hand, sphenoid sinus of the pre-sellar type frequently presents difficulties during hypophysectomy, and when the sinus is of conchal type the operation is strongly contra-indicated. However with the surgeon informed in advance, different tools can make such an approach feasible[20].

Inter-sinus septum (Figure No. 5) –

The median partition of the sphenoid sinuses normally occupies an antero-posterior position and vertical plane, and due to irregularity in the pneumatization of the sinuses, usually deviates to the right or left posteriorly in the region of the pre- and post-sphenoid synchondrosis[18]. This septum must be removed to expose the floor of the sella. The septum usually deviates to one side, dividing sinus into two unequal cavities, thereby resulting in asymmetrical appearance of the floor of sella turcica[20].

In our study we found termination of inter-sinus septa on bony wall covering internal carotid artery in 7 cadavers (23 percent), on bony wall covering optic nerve in 3 cadavers (10 percent), in 10 percent of the cadavers it was lying in the midline and in 80 percent of the cadavers it was deviated on either side of the mid-line. S. Elwany et al.

(1983) found midline septum in 27 percent of cases and in 73 percent of cases it was deviated. D. Sethi et al. (1995) observed termination of inter-sinus septum onto the internal carotid artery in 40 percent of cases while Renn and Rhoton (1975) found it in 32 percent of cases.

This means that the inter-sinus septum should never be used as a guide to the midline during hypophysectomy. The vomer can be used as a more accurate guide to the midline[2]. It is wise to use extreme caution while removing the terminal septum in order to prevent accidental injury to internal carotid artery or optic nerve[4].

<u>Sphenoid dominance</u> (Figure No.7) -

In our cadaveric study we found right dominance in 16 cases (54 percent) and in 8 cases left dominance (27 percent). D. Sethi et al. (1995) observed right dominance in 27 percent cases and left dominance in 33 percent cases.

<u>Accessory septae and its termination</u> (Figure No. 4) -

Bone formed at the line of fusion of bony nuclei is denser than the bone immediately adjacent to it, and, therefore, it is more resistant to pneumatization. This fact explains the occurrence of partial septa in, and the various forms assumed by them, in the sphenoid sinus.

In our study, we found accessory septa in 13 cadavers (43 percent). In 7 cadavers (23 percent) it terminated on internal carotid artery, in 2 cadavers (6 percent) it terminated on optic nerve and in 4 cadavers (13 percent) it terminated either over inter-

sinus septum or on the lateral wall. S. Elwany et al. (1983) observed accessory septa in 76 percent of cases. Another study by S. Elwany et al. (1999) found accessory septa in 68 percent of cadavers. In 13 percent of cadavers it terminated over internal carotid artery and in 6 percent of cadavers it terminated over optic nerve. Sareen D. et al. (2005) found inter-sinus septae in 80 percent of cases.

Dimensions of sphenoid sinus -

In our study average dimensions of the sphenoid sinus were found to be: antero posterior- 2.5 cm, transverse- 2.1 cm and vertical- 2.2 cm. Average dimensions in the study by S. Elwany et al. (1983) were antero posterior- 2.4 cm, transverse- 1.6 cm and vertical- 2 cm. Sareen D. et al. (2005) observed average dimensions in their study as follows: antero posterior- 2.5 cm, transverse- 2.8 cm and vertical- 2.2cm.

Size of sphenoid sinus -

If pneumatization of the sinus is retarded on one side but unrestricted on other, then the mucosa of the unrestricted side encroaches over the bone of restricted portion during the process of bone absorption. This leads to disparity in size of the two sinuses.

In our study, the volume ranged between 2.2 to 9.4 ml. In other studies it ranged between 2.7 to 9.1 ml (S. Elwany et al., 1983), 6 to 7.5 ml (Simpson et al., 1967) , 4 to 9 ml (Ballenger, 1977) and 3 to 10 ml (Sareen D. et al., 2005).

Relations of neuro-vascular structures (Figure No. 10) -

Pneumatization of the sphenoid sinus was halted by the presence of softer materials such as cartilage, connective tissue or blood vessels. This explains variation in the relations of neuro-vascular structures.

S. Elwany et al. (1999) observed protrusion of internal carotid artery in 18 percent of cases and protrusion of optic nerve in 29 percent of sinuses. They found onodi cell in 7.5 percent of sinuses. D. Sethi et al. (1995) observed internal carotid artery bulge in 7 percent of sinuses and dehiscent optic canal in 3 percent of sinuses. They found onodi cell in 3 percent of sinuses. Renn and Rhoton reported protrusion of internal carotid artery in 71 percent of sinuses and dehiscence in 4.8 percent of sinuses. Kennedy et al. (1990) reported dehiscence of internal carotid artery in 22 percent of his reported cases. Fuji et al. (1979) reported optic nerve bulge in 40 percent of his specimens. In our study we found protrusion of internal carotid artery in 25 percent of sinuses and optic nerve bulge in 10 percent of sinuses in cadavers.

Findings in CT scan study –

Hewaidi G. H. & Omami G. M.[6] (2008) studied paranasal CT scans of 300 Libian patients, age ranging between 18-82 years. Contiguous slices of 2 mm thickness from anterior to posterior wall of sphenoid sinus centered to the nasal cavity & paranasal sinuses were studied. All the parameters related to sphenoid sinus were studied. Axial & coronal views were used for the study. Comparison between coronal and axial CT scans to determine variations of paranasal sinuses was done.

Ossama Hamid et al.[20] studied 296 magnetic resonance imaging (MRI) and CT scans of patients of pituitary adenoma. Pre-operative & post-operative axial & coronal CT scans were used to study anatomical variations of sphenoid sinus. Impact of these variations on surgical approach and surgical complications were studied.

Robert M. & Galdino MD[16] (1998) and G. Tetani[10] (1987) studied paranasal CT scans from surgeon's point of view. They studied anatomical variations of sphenoid sinus and relation of neurovascular structures. According to the variations observed by them, they suggested precautions to be taken by surgeons while approaching sphenoid sinus during surgical procedures.

Extent of sphenoid sinus pneumatization (Figure Nos. 13, 14, 15) -

In CT scan study, we observed 1 conchal (1.6 percent), 8 pre-sellar (14 percent), 14 sellar (23 percent) and 37 post-sellar (61 percent) type of pneumatization. In other study, Ossama Hamid et al. (2008) observed 2 percent conchal, 21 percent pre-sellar, 54.7 percent sellar and 22.3 percent post-sellar type of pneumatization. In our study we observed pneumatization of anterior clinoid process in 2 cases (34 percent), that of greater wing of sphenoid in 2 cases (34 percent) and of pterygoid process in 4 cases (67 percent). Hewaidi GH et al. (2008)[6] observed pneumatization of anterior clinoid process in 15 percent, of greater wing of sphenoid in 20 percent and that of pterygoid process in 29 percent of the patients[6]. Bolger et al. identified pneumatization of anterior clinoid process in 13 percent and of pterygoid process in 43 percent patients[38]. John Earwaker (1993) found pneumatization of greater wing of sphenoid in 20 percent of patients. De

Lano et al. (1996) found anterior clinoid process pneumatization in 4 percent of patients[40]. Sirikci et al. (2000) found anterior clinoid process pneumatization in 29 percent of patients[41]. Birsen et al. (2006) found anterior clinoid process pneumatization in 24 percent of patients[42].

Review of CT scan images for the presence of pneumatization of anterior clinoid process, greater wing of sphenoid and pterygoid process are more sensitive than cadaveric dissection. Pterygoid process pneumatization, when present, is an important pathway for access to the central skull base. These techniques may provide route for endoscopic repair of CSF leaks and endoscopic biopsy of skull base lesions[43].

Termination of inter-sinus septum (Figure No.14) –

In CT scan we found midline inter-sinus septum in 29 percent of cases, in 20 percent of cases it terminated on the bony wall covering the internal carotid artery and in 10 percent of cases on bony wall covering optic nerve. Ossama Hamid et al. (2008) observed that in 32 to 40 percent of cases it deviated from the midline and terminated over the internal carotid artery.

Sphenoid dominance (Figure No.14) -

In CT scan study we observed right dominance in 20 cases (66 percent) and left dominance in 10 cases (33 percent).

<u>Accessory septae and their termination</u> (Figure No.16) –

In CT scan study we observed accessory septa in 11 cases (20 percent) out of which in 4 cases they terminated on internal carotid artery (6.6 percent) and in 1 case it terminated over optic nerve (1.6 percent). In another study done by Ossama Hamid (2008), they found accessory septa in 10.8 percent of cases.

<u>Dimensions of sphenoid sinus</u> –

The mean and standard deviations of all dimensions for male and female respectively were: right antero-posterior 2.7 ± 0.42 and 2.7 ± 0.53 cm, left antero-posterior 1.9 ± 0.76 and 2.7 ± 0.55 cm, right transverse 2.2 ± 0.53 and 2.1 ± 0.62 cm, left transverse 1.7 ± 0.56 and 2.1 ± 0.54 cm, right vertical 2.4 ± 0.33 and 2.3 ± 0.43 cm, left vertical 2.1 ± 0.61 and 2.2 ± 0.43 cm. We found statistically significant correlation for right antero-posterior dimension.

<u>Relations of neuro-vascular structures</u> (Figure Nos.14, 15, 16) –

In CT scan study, we observed protrusion of internal carotid artery in 15 percent, optic nerve in 33 percent, vidian nerve in 5 percent and maxillary nerve in 5 percent of sinuses. In 1 case onodi cell was observed. Hewaidi GH et al. (2008) in their CT scan study observed protrusion of internal carotid artery in 41 percent of patients and dehiscence of the artery in 30 percent. Protrusion of optic nerve was observed in 35.6 percent and dehiscence in 30.6 percent of patients. Maxillary nerve protrusion was observed in 24.3 percent and dehiscence of the nerve in 13 percent of patients. Vidian nerve protrusion was found in 27 percent of patients. Fuji et al. (1979) found 8 percent

dehiscent carotid arteries, 4 percent dehiscent optic nerve. Kennedy et al. (1990) found dehiscence of internal carotid artery in 25 percent of patients. Birsen et al. (2006) found protrusion of internal carotid artery in 30.3 percent and dehiscence in 3.5 percent of patients. They noticed protrusion of maxillary nerve in 24.3 percent. Sirikci et al. (2000) reported protrusion of internal carotid artery in 26.1 percent of patients and dehiscence of the artery in 23 percent. Lang and Keller (1978) reported that the vidian canal was protruded into the sinus cavity in 18 percent.

Protrusion of the internal carotid artery and/ or optic nerve is associated with ipsilateral pneumatization of the anterior clinoid process. Protrusion of the vidian canal into the sinus cavity is associated with pneumatization of the pterygoid process, on the same side.

Findings in live patients –

In live subjects, we found round ostium in 24 percent and oval in 18 percent of cases. (Figure Nos. 8 and 9).

We found accessory septum in 64 percent of cases. In 3 cases it terminated over internal carotid artery and in 1 case it terminated over optic nerve.

Protrusion of internal carotid artery was found in 32 percent of patients and dehiscence in 8 percent of cases. Optic nerve bulge was observed in 24 percent of cases. Dehiscence of optic nerve was not observed.

CONCLUSION

The present study was done to explore the gross anatomy of sphenoid sinus and its relations. The complex and diverse relations of the sphenoid sinus have a dual significance. Infection and tumors can easily spread to important neurovascular structures and intracranially also. Surgeries over sphenoid sinus and pituitary gland can cause iatrogenic injuries to important structures and at times fatal complications. With the advent of Endoscopes and newer imaging techniques, surgeries over sphenoid sinus are now safer.

In trans-nasal approach to sphenoid the ostium of sphenoid is first landmark to be identified. It is present in the spheno-ethmoidal recess and its location demonstrates wide variations. Inter-sinus septae and crest are very commonly found and more importantly they often terminate on optic nerve or carotid artery prominence.

Sphenoid sinus shows various types of pneumatization, and when pneumatization spreads outside the body of sphenoid sinus it creates various recesses. These place the sinus in close proximity to important structures like the maxillary nerve or the vidian nerve. The lateral wall of sphenoid sinus is hallmarked by indentations of optic nerve and carotid artery. Many a times the bony covering is very thin or dehiscent. Onodi cells are the posterior ethmoid cells which lie supero-lateral to sphenoid sinus and when present place the optic nerve at considerable risk.

Newer techniques are emerging for safety of patients due to complex and highly variable anatomy of the sphenoid sinus. Now intra-operative fluoroscopic imaging or intra-operative navigational devices are used to confirm surgical landmarks making these techniques very safe.

SUMMARY

Today modern surgery is more and more focused on minimal invasive surgeries. Functional endoscopic sinus surgery (FESS) is one of the minimal invasive surgeries. Para-nasal sinus diseases and their complications are common, and may require surgical intervention. FESS is important for any pathology in the para-nasal sinuses. Trans-sphenoid approach to pituitary gland is now mainstay of modern pituitary surgery. Sphenoid sinus is surrounded by internal carotid artery, optic nerve, maxillary nerve and vidian nerve. Injury to these structures gives rise to inevitable complications. Most of the complications are due to wide variation in anatomy of sphenoid sinus and its relations. This study is an attempt to know the percentage of variations in North Karnataka population through cadaveric dissection and CT scan study. We used 30 cadavers available in the Anatomy Department of J. N. Medical College, Belgaum and 30 CT scan (age range 18-85 years) from Radiology Department of KLE's Dr. Prabhakar Kore Hospital and Research Center, Belgaum. Twenty-five patients from ENT Department of KLE's Dr. Prabhakar Kore Hospital and Research Center, Belgaum undergoing sphenoid sinus surgery were also included in the study.

Gross and endoscopic study was done in cadavers. Dimensions and relations of sphenoid sinus were noted and tabulated. Findings from CT scan study were tabulated separately.

In 20% of cadavers the sphenoid sinus was pre-sellar, in 14% it was sellar and in 66% it was post-sellar. Conchal type of sphenoid sinus was absent. Bony septa or crests were seen in 13 cadavers, out of which in 4 cadavers (32%) they were bilateral and in remaining 9 cadavers (69%) they were unilateral. The septa terminated on bone covering

internal carotid artery (ICA) in 7 cadavers while in 2 cadavers they terminated on the bone covering optic nerve (ON). Dimensions of the sphenoid sinus were: antero-posterior (2.5 ± 0.5 cm), transverse (2.4 ± 0.4 cm) and vertical (2.2 ± 0.6 cm). The sphenoid ostium was oval or rounded in 28 and 32 cases respectively. The average size of sphenoid sinus was 5.7 ml. In 14 cadavers we found right dominance and in 8 cadavers left dominance. In 22 cadavers inter-sinus septum terminated on sites other than normal position. In 8 cadavers it terminated over bone covering internal carotid artery and in 3 cadavers it terminated on bone covering optic nerve. In rest of the cadavers it terminated away from the midline. Carotid prominence was found in 15 sinuses and optic nerve bulge was found in 6 sinuses.

Our findings of CT scan study are as follows: out of 60 sinuses, pre-sellar-8 (13.3%), sellar-14 (23.3%) and post-sellar-37 (61.6%) and in 1 subject left side sinus was conchal. Pnematization of greater wing of sphenoid was observed in 2 sinuses (2.2%), that of pterygoid process in 4 sinuses (6.6%) and of anterior clinoid process in 2 sinuses (2.2%). We also found onodi cell in 1 sinus (1.4%). Accessory septae were observed in 11 sinuses (18.2%), single in 7 sinuses (11.6%) and multiple in 4 sinuses (6.6%). In 6 sinuses these septae terminated over lateral wall of sinuses (10%) while in 4 sinuses they terminated over bony wall covering internal carotid artery (6.6%) and in 1 sinus on bony wall covering optic nerve (1.4%). The mean, standard deviations of all dimensions for male and female respectively were: right antero-posterior 2.7 ± 0.42 and 2.7 ± 0.53 cm, left antero-posterior 1.9 ± 0.76 and 2.7 ± 0.55 cm, right transverse 2.2 ± 0.53 and 2.1 ± 0.62 cm, left transverse 1.7 ± 0.56 and 2.1 ± 0.54 cm, right vertical 2.4 ± 0.33 and 2.3 ± 0.43 cm, left vertical 2.1 ± 0.61 and 2.2 ± 0.43 cm. We found statistically significant

correlation for right antero-posterior dimension. Right dominance was observed in 20 persons while left dominance in 10 persons. Protrusion of ICA was observed in 9 sinuses (15%). Protrusion of optic nerve was observed in 2 sinuses (33%). Protrusion of maxillary nerve and vidian nerve were observed in 3 sinuses (5%). Dehiscent bony wall was not observed in any sinus. Onodi cell was observed in 1 sinus (13%).

Endoscopic findings in live patients (18 male and 7 female) were: in 14 patients sphenoid ostium was round and in 11 patients it was oval. Accessory septa were observed in 16 patients (64%). In 3 patients (12%) accessory septa inserted into the bony wall covering of the carotid arteries and only in 1 patient it inserted into the bony wall covering of the optic nerve. Optic nerve bulge was observed in 6 patients (24%). Bony wall covering optic nerve was intact in all patients. Internal carotid artery bulge was observed in 8 patients (32%). Dehiscent bony wall was observed in 2 patients (8%).

We hope that this data will be helpful for surgical application.

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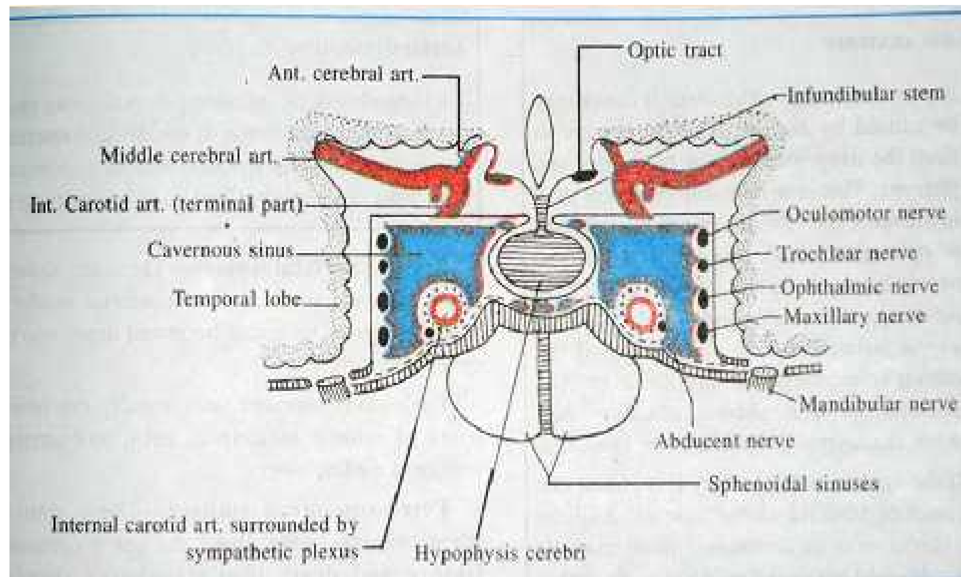

Figure No. 1

Relations of Sphenoid Sinus

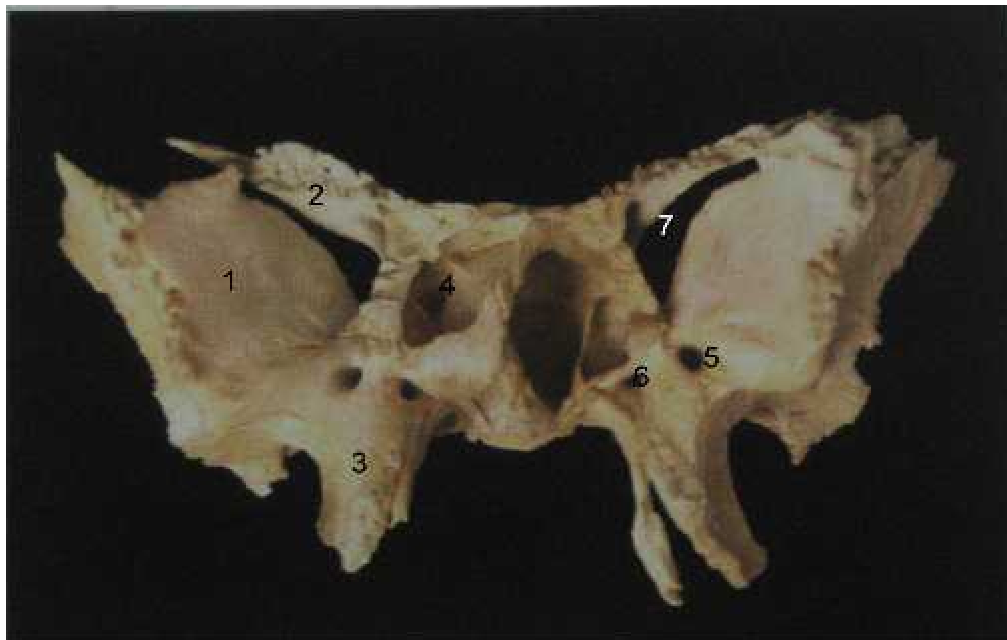

Figure No. 2

Sphenoid bone showing 1) Greater wing; 2) Lesser wing; 3) Pterygoid process; 4) Sphenoid sinus; 5) Foramen rotundum ; 6) Pterygoid canal; 7) Superior orbital fissure.

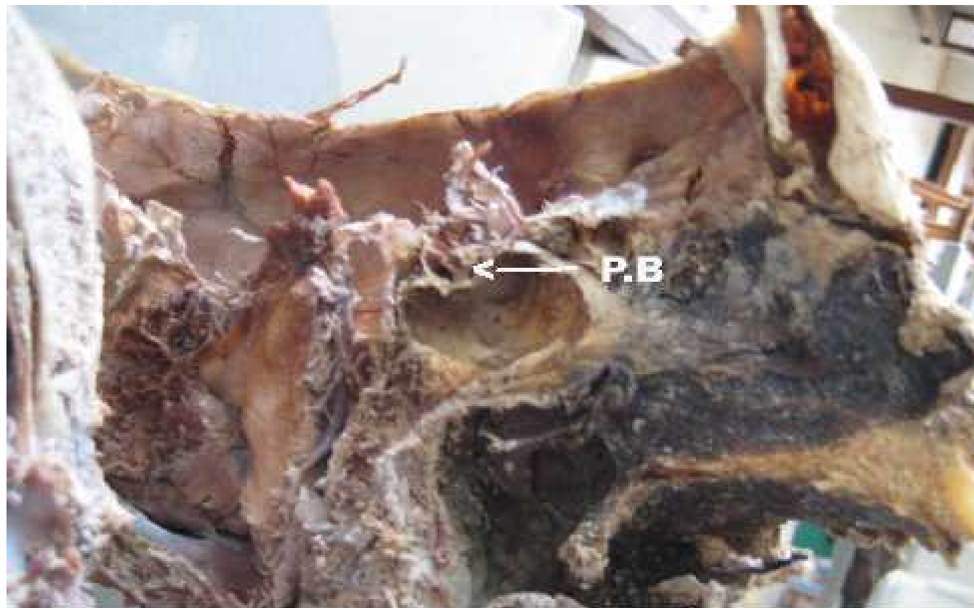

Figure No. 3

Post-sellar sinus with pituitary bulge (P.B.)

Figure No. 4

Post-sellar sinus with accessory septum (A. S.)

Figure No. 5

Sphenoid sinus showing inter-sinus septum (ISS).

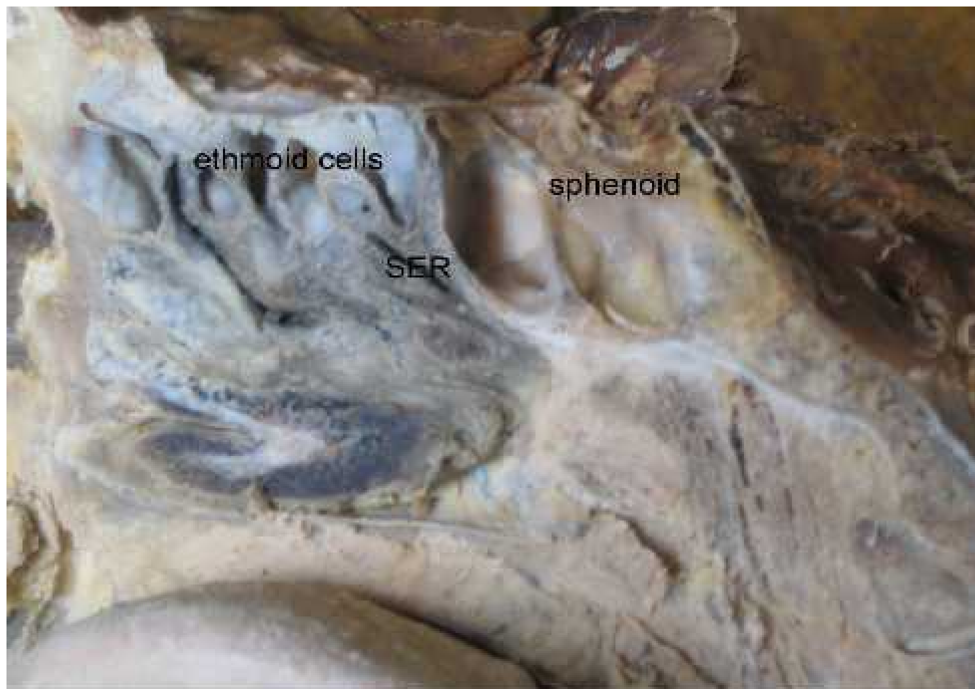

Figure No. 6

Relations of sphenoid sinus and spheno-ethmoid recess (SER)

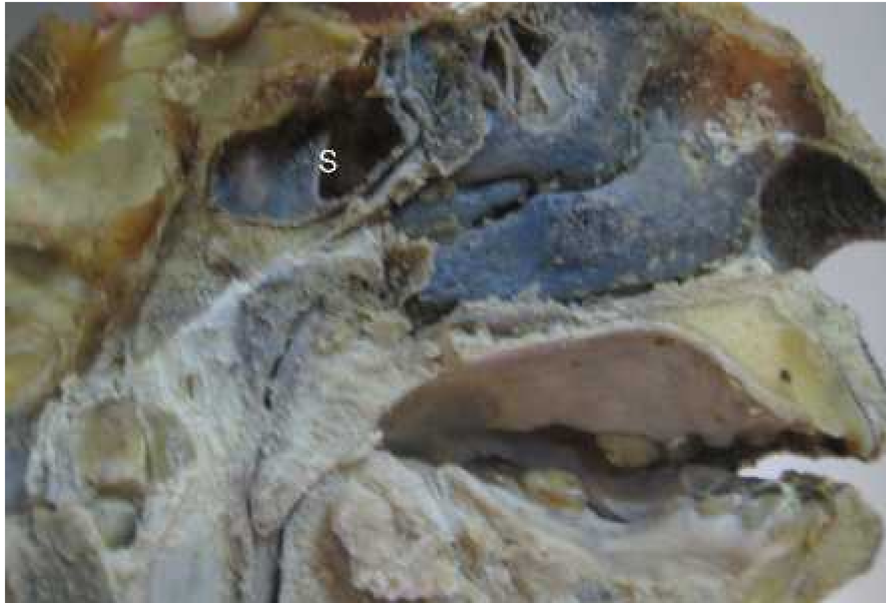

Figure No. 7

Figure showing right sphenoid (S) dominance

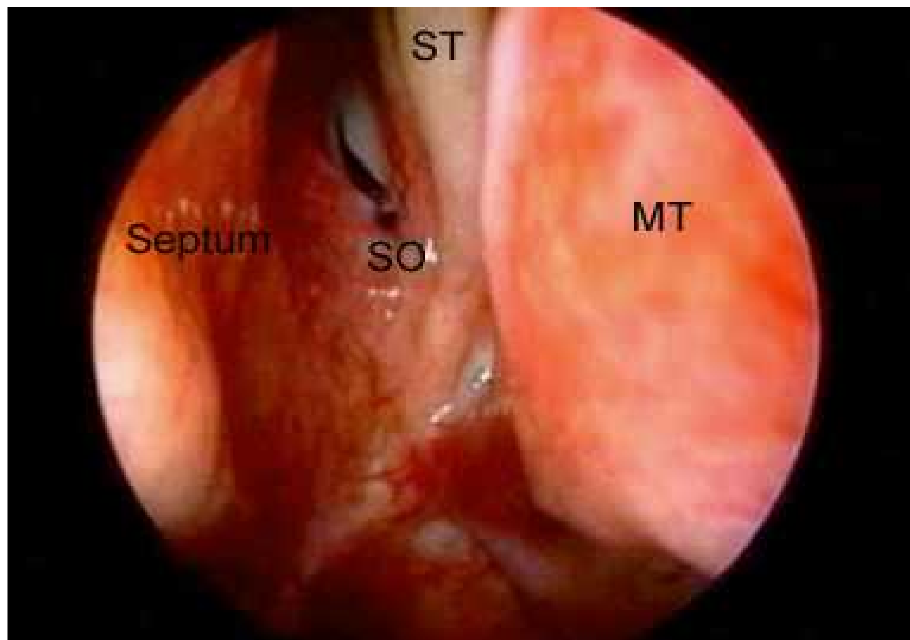

Figure No. 8

An oval sphenoid ostium (SO), MT- middle turbinate, ST- superior turbinate.

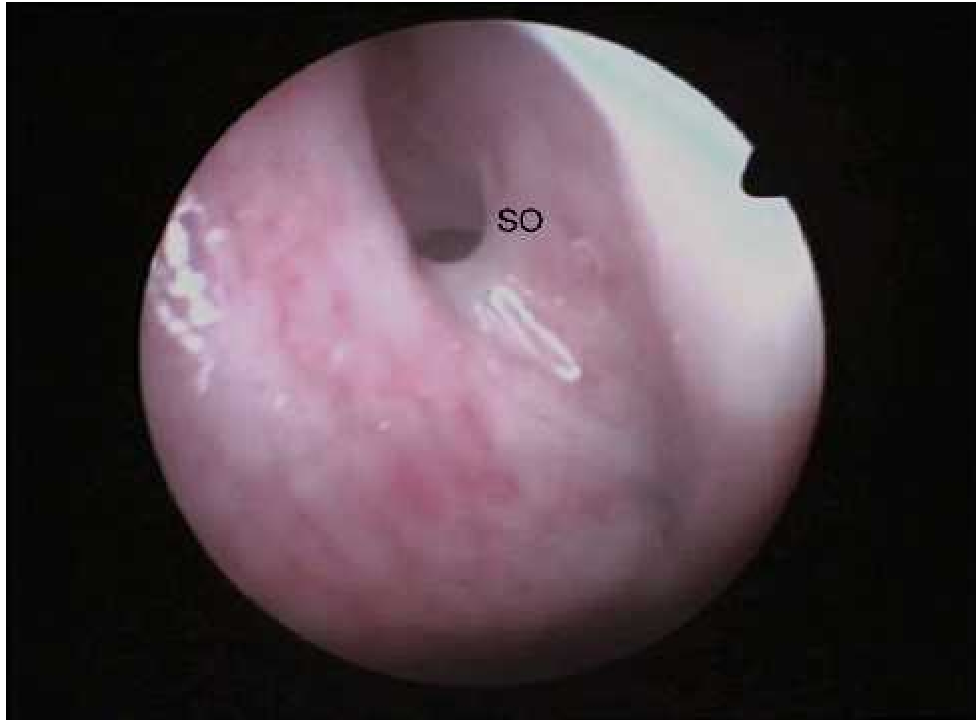

Figure No. 9

An round sphenoid ostium (SO)

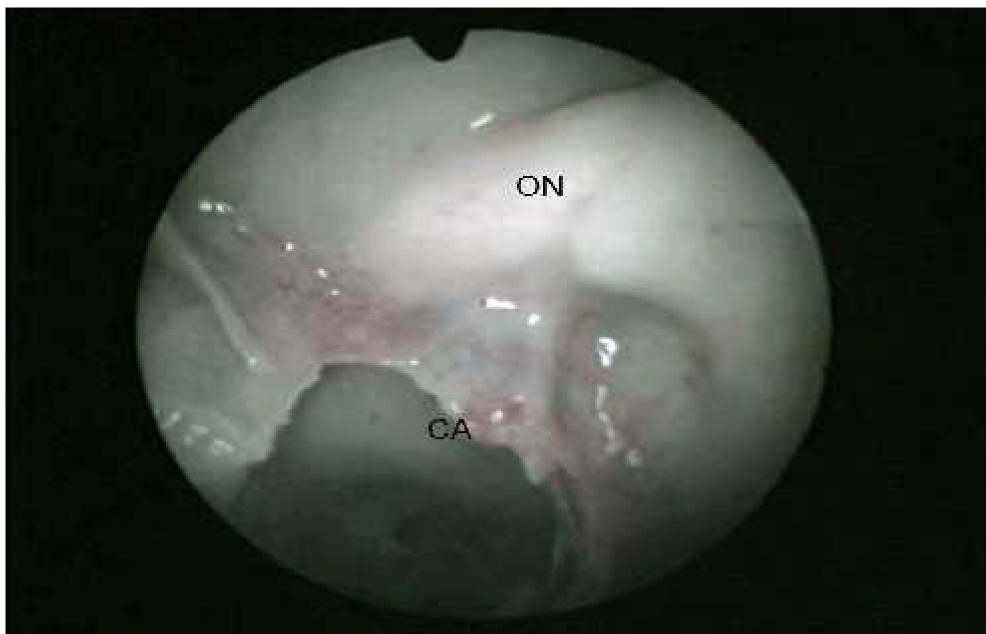

Figure No. 10

Endoscopic view showing Optic nerve bulge (ON) and Carotid artery (CA) bulge.

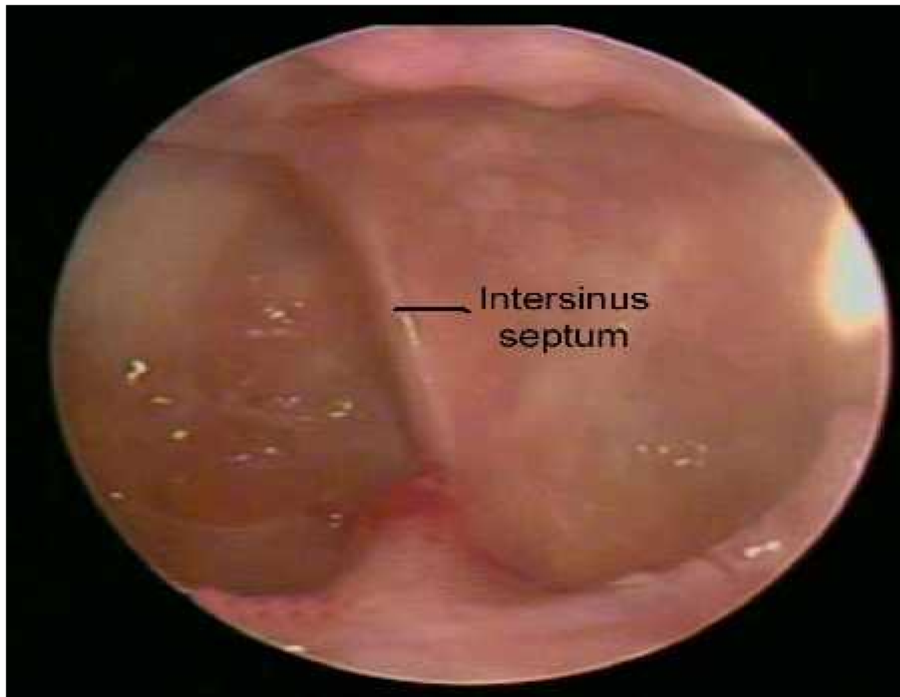

Figure No. 11

Post-operative view showing position of inter-sinus septum

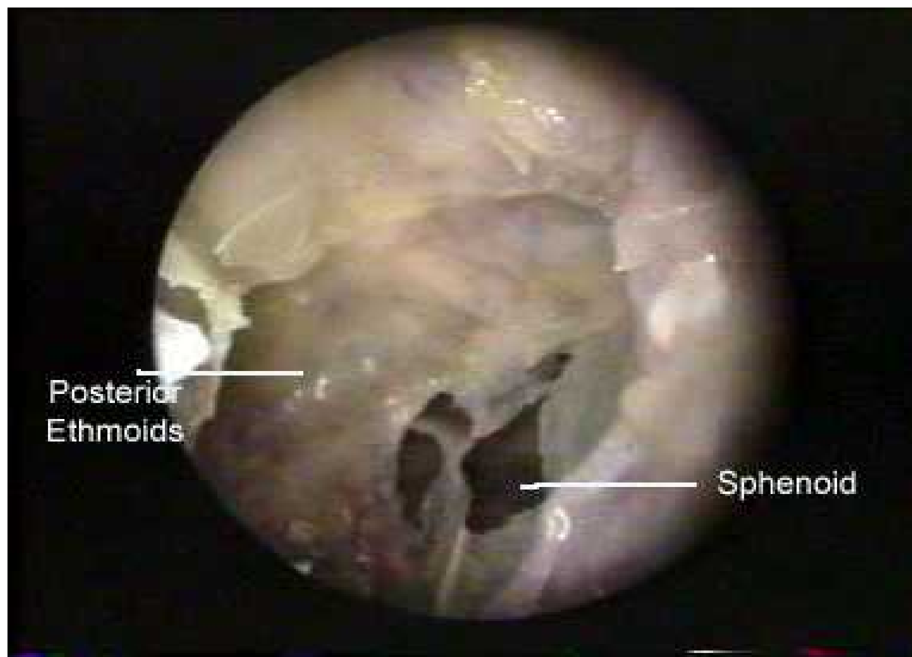

Figure No. 12

Relation of posterior ethmoids to sphenoid

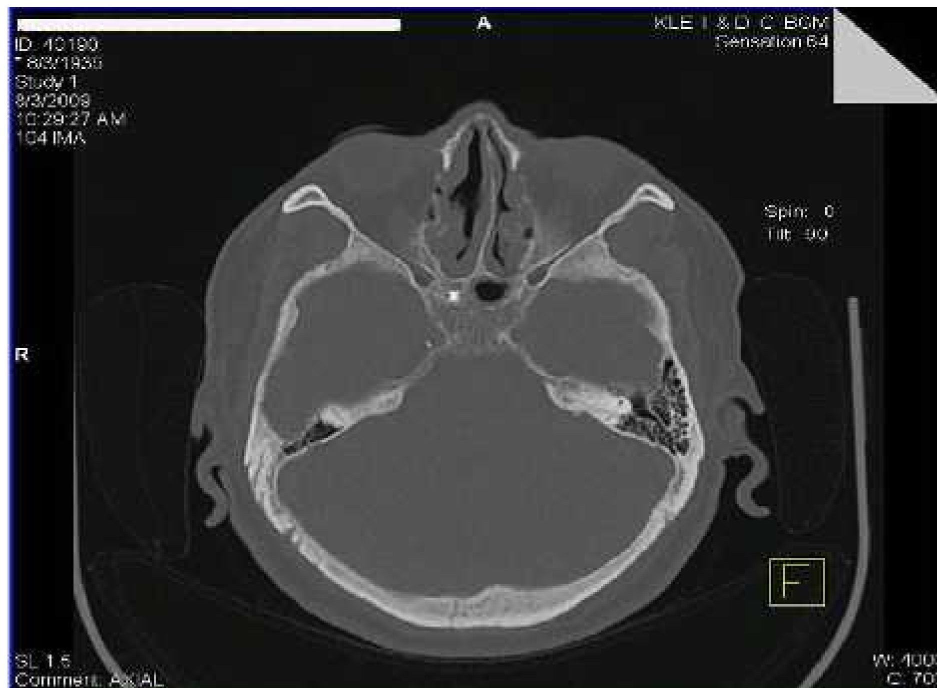

Figure No. 13

CT scan showing right conchal (*) type of pneumatization

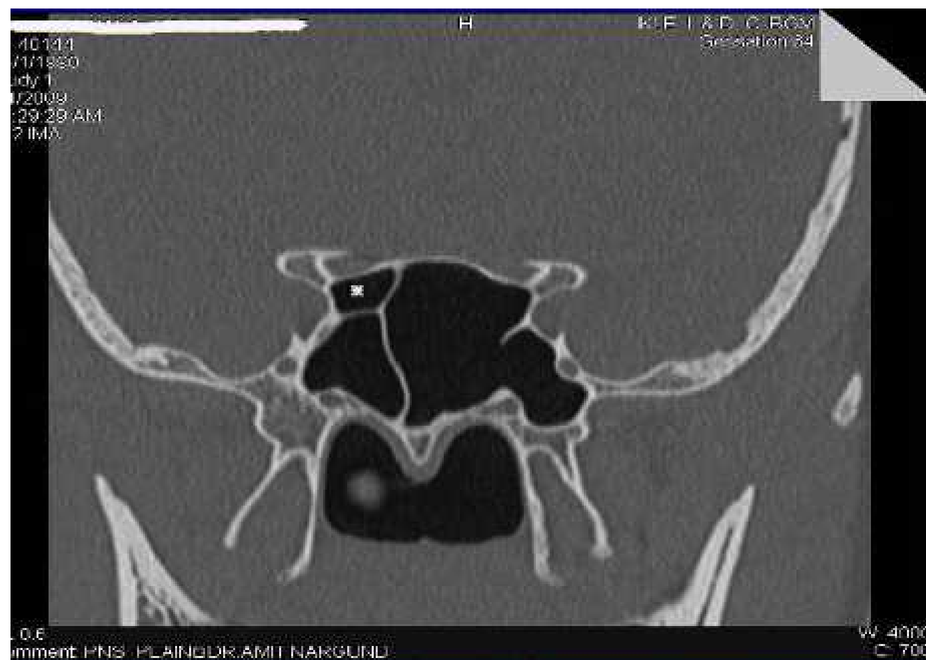

Figure No. 14

CT scan showing left sphenoid dominance and Onodi cell (*)

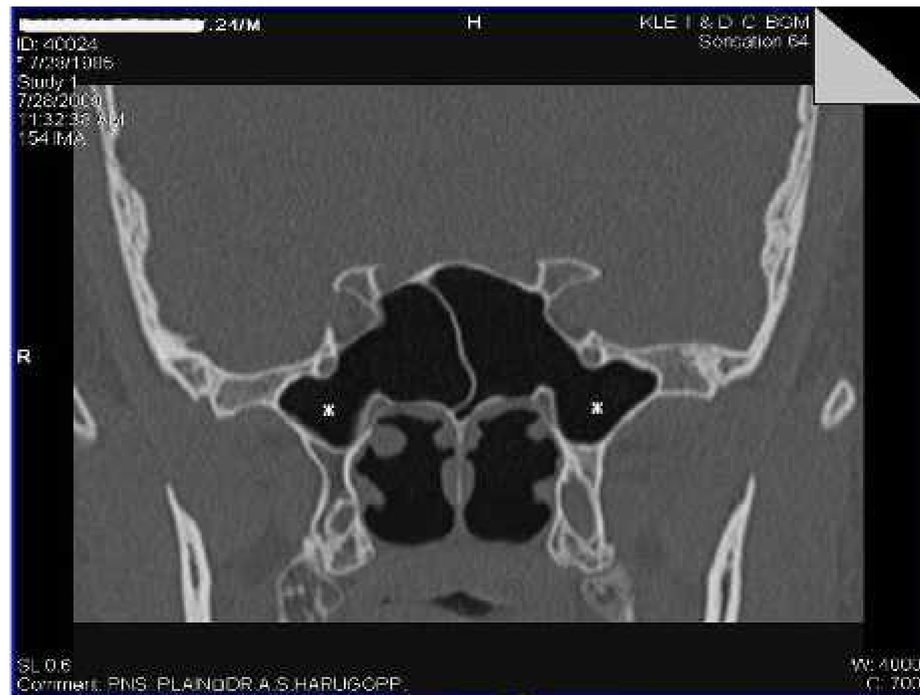

Figure No. 15

CT scan showing pneumatized pterygoid process (*)

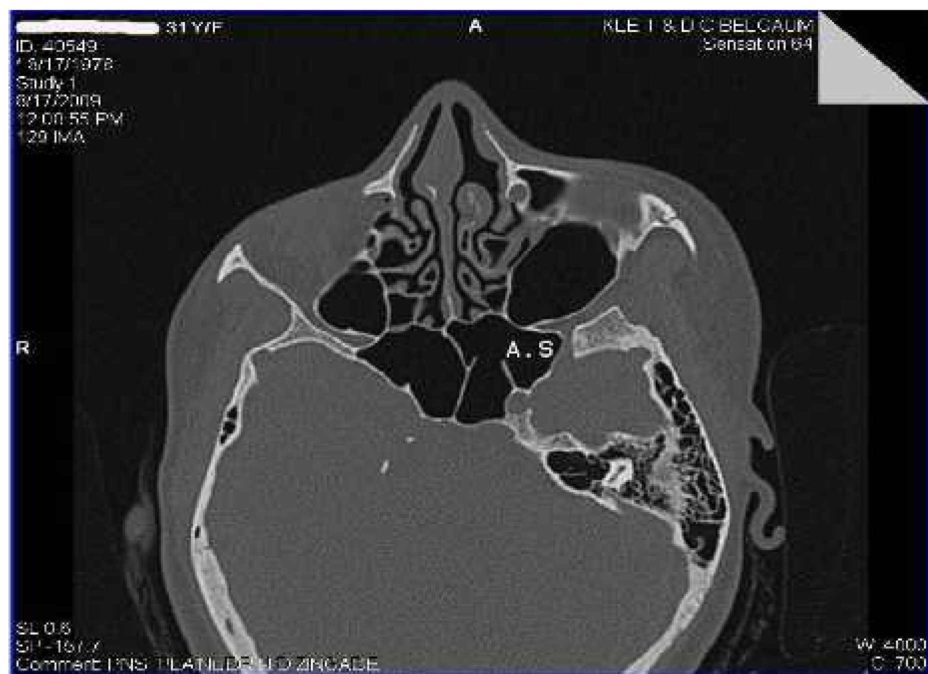

Figure No. 16

CT scan showing accessory septum (AS) ending on internal carotid artery

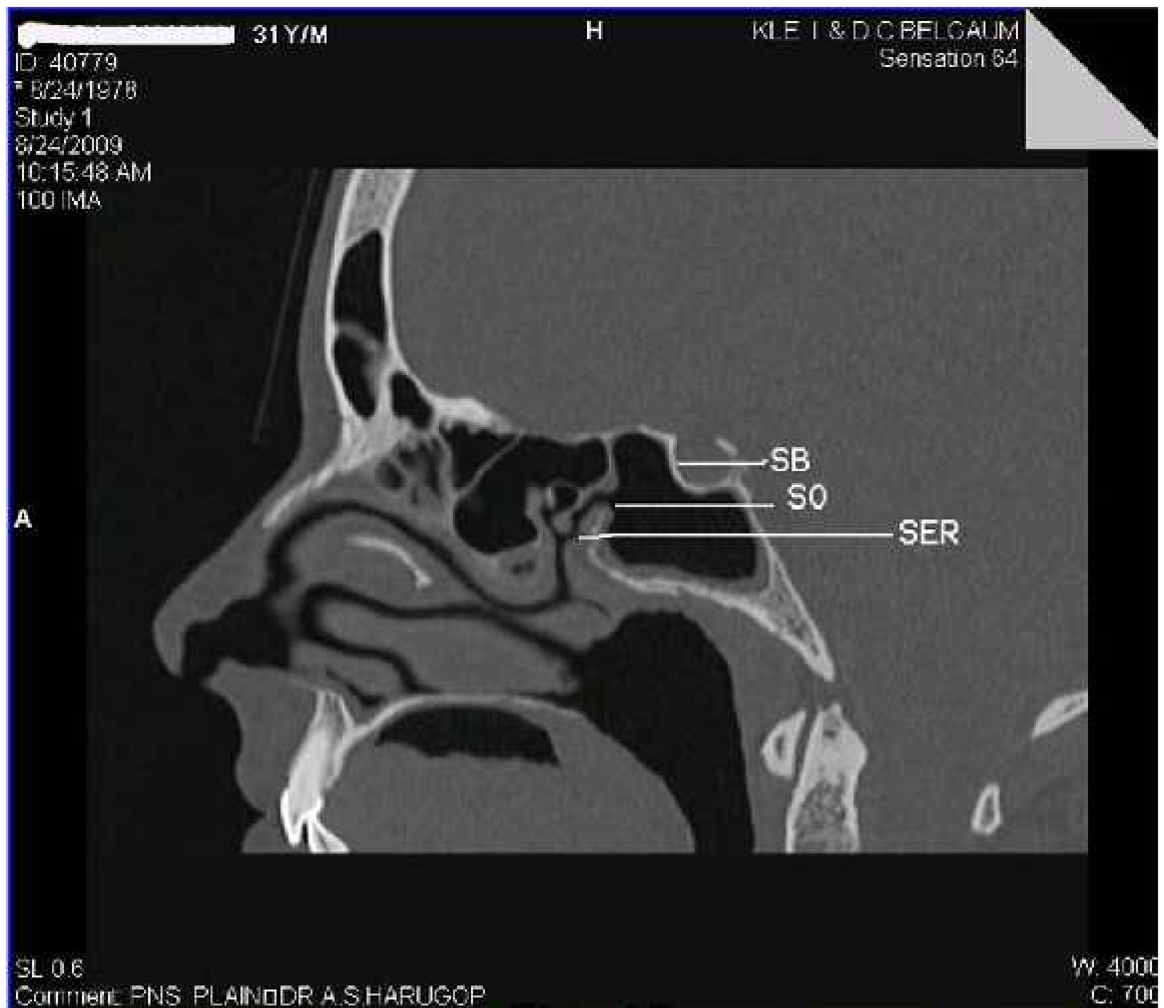

Figure No. 17

CT scan showing sellar bulge (SB), sphenoid ostium (SO)

and spheno-ethmoid recess (SER).

LIST OF ABBREVIATIONS USED IN MASTER CHART

Sr. No.-	Serial number
M-	Male
F-	Female
SO-	Sphenoid Ostium
R-	Right
L-	Left
r-	round
o-	oval
ISS-	Inter-sinus septa
ICA-	Internal carotid artery
ON-	Optic nerve
AP-	Antero-posterior
ml-	Mililiter
GWS-	Greater wing of sphenoid sinus
PP-	Pterygoid process
• -	Anterior clinoid process, PP and GWS Pneumatization
-	Anterior clinoid process and PP Pneumatization
✪	Multiple septae
LW-	Lateral wall
VN-	Vidian nerve
MN-	Maxillary nerve

PROFORMA

1. Name: ____ .

2. Age :________ Years

3. Sex: __________ .

4. Address: __________________________________ .

5. Contact telephone number: _____________________ .

6. Native of _______________(Place), ______________________(State).

7. Any history of
a) Sinus surgery :________
b) Injury to face :________
c) Surgeries on face :________

8. Type of sphenoid sinus: conchal, pre-sellar; sellar; post-sellar
9. Shape of sphenoid ostium: a) Round
b) Oval
10. Termination of inter-sinus septa: a) Normal
b) Internal carotid artery
c) Optic nerve

11. Accessory septa or crests and its termination:

a) Internal carotid artery: _____ b) Optic nerve: _____ c) Other: ____ .

12. Dimensions of sphenoid sinus (cm):

a) Antero-posterior: ____ b) Transverse: ____ c) Vertical: _____.
13. Volume of sphenoid sinus:

14. Sphenoid dominance: a) Right- _____________ b) Left: ____________.

15. Relations of sphenoid sinus

	Internal Carotid Artery	Optic Nerve	Maxillary Nerve	Vidian Nerve	Onodi cell
Right					
Left					

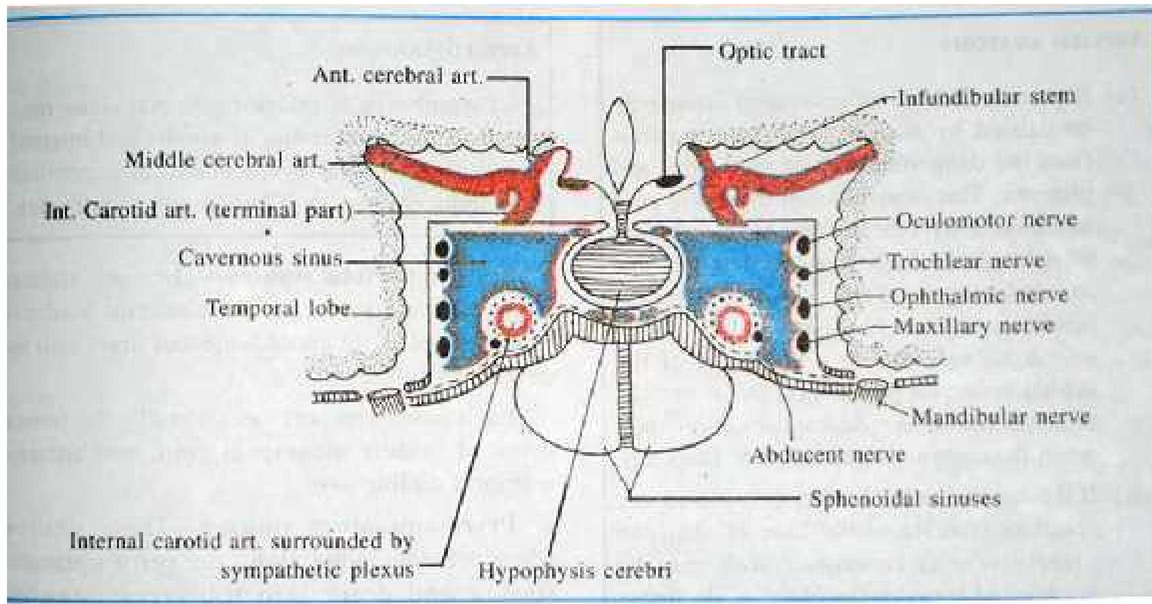

Fig. 1
Relations of sphenoid sinus

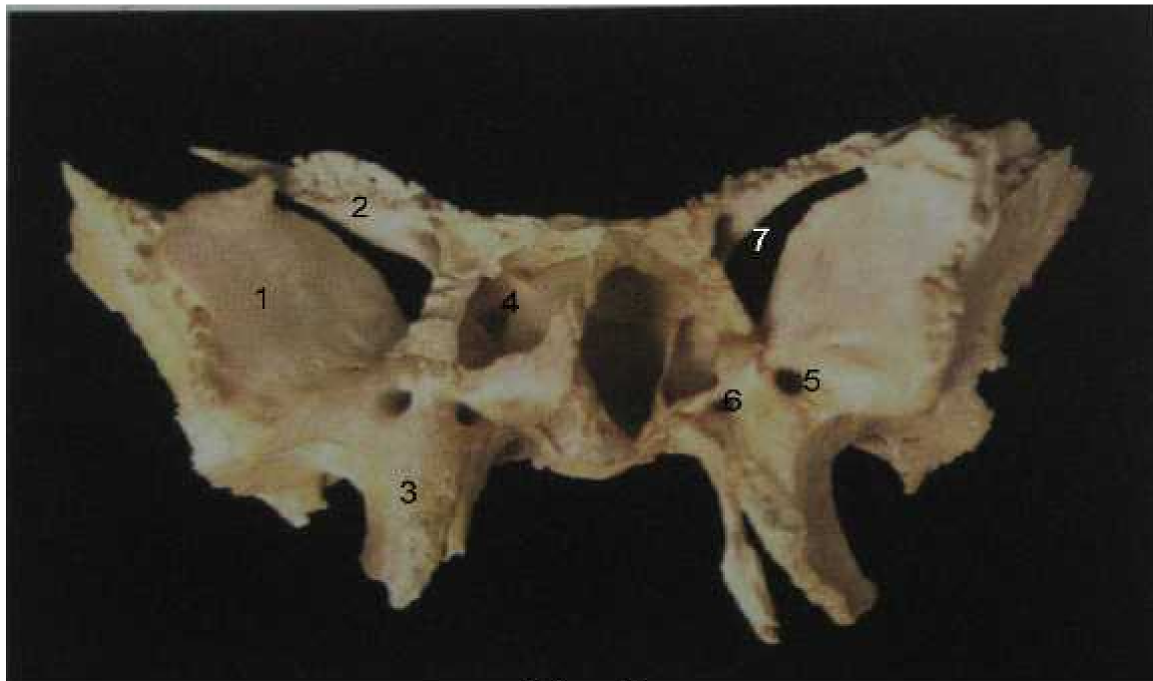

Fig. 2
Sphenoid bone showing 1)Greater wing; 2)Lesser wing; 3)Pterygoid process; 4)Sphenoid sinus; 5)Foramen rotundum; 6)Pterygoid canal; 7)Superior orbital fissure.

Fig. 3

Post-sellar sinus with pituitary bulge (P.B.)

Fig. 4

Post-sellar sinus with acessory septum (A. S.)

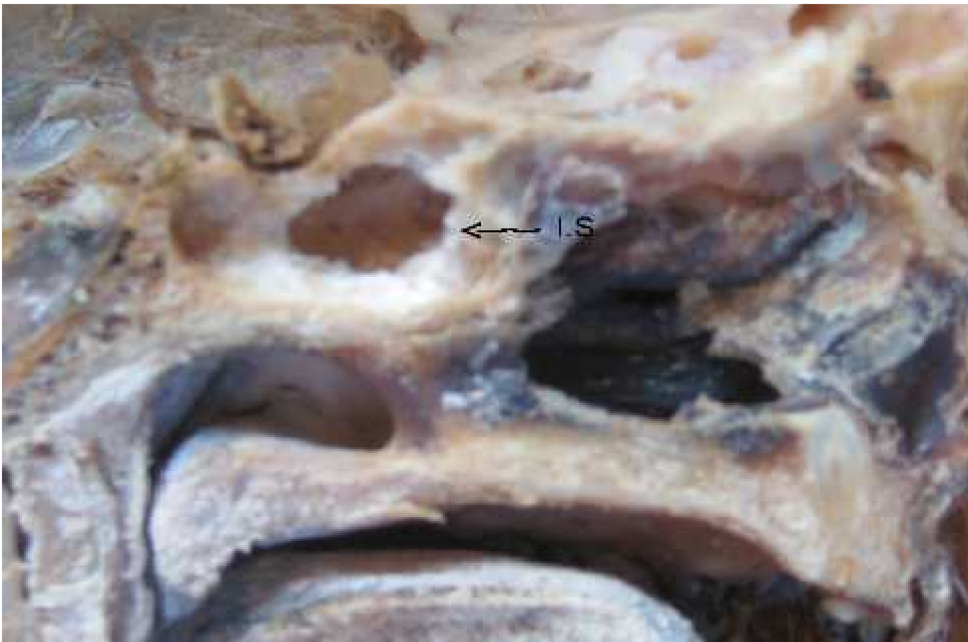

Fig. 5

Sphenoid sinus showing inter-sinus septum

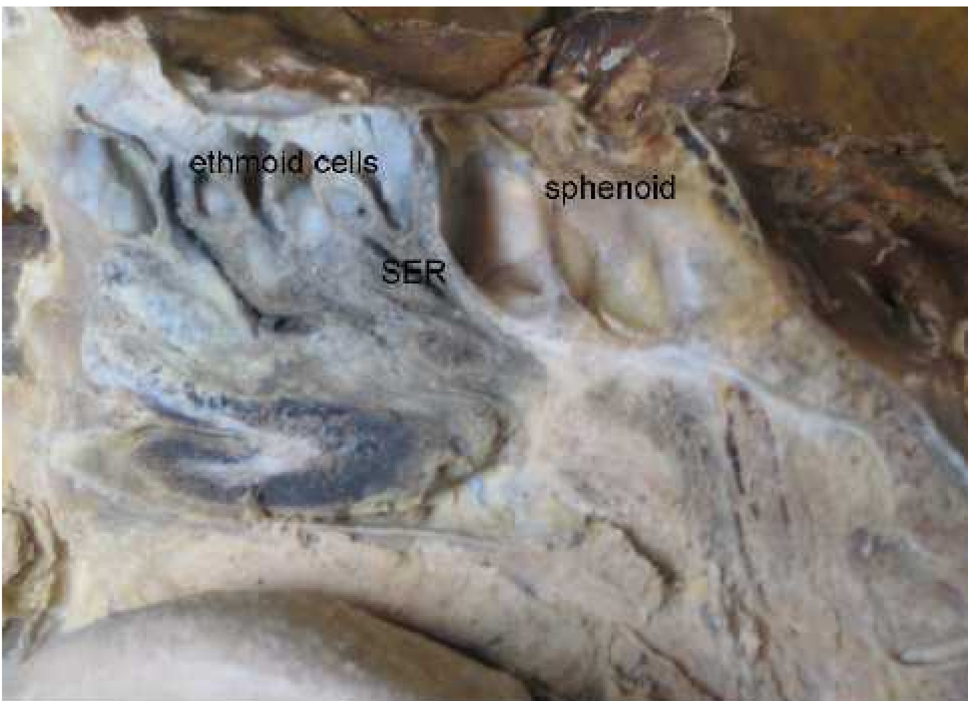

Fig. 6

Relations of sphenoid sinus and spheno-ethmoid recess (SER)

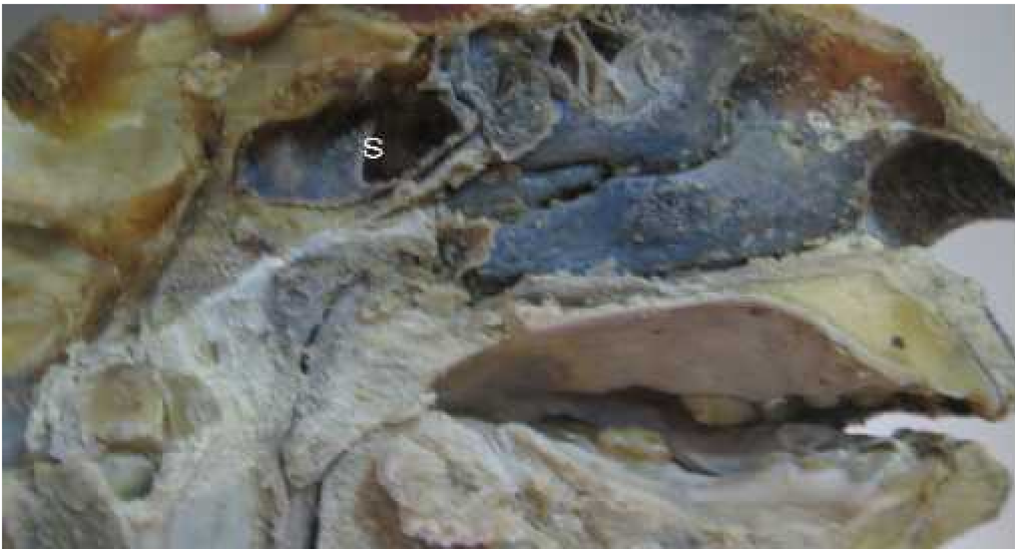

Fig. 7

Figure showing right sphenoid (S) dominance

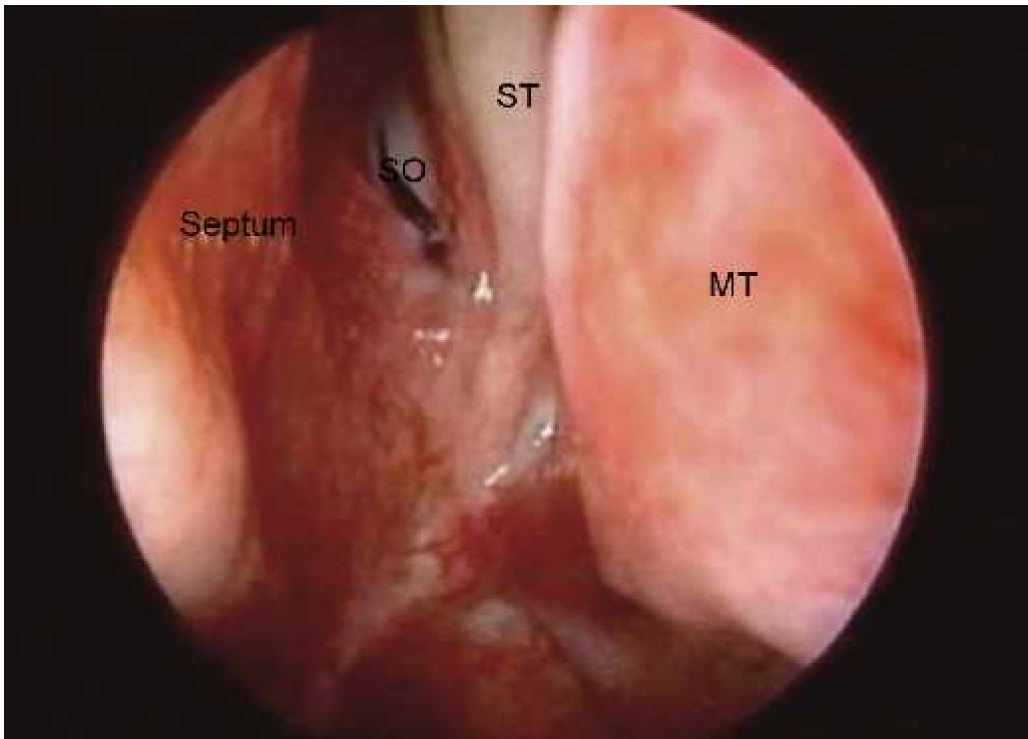

Fig. 8

An oval sphenoid ostium (SO), MT- middle turbinate, ST- superior turbinate.

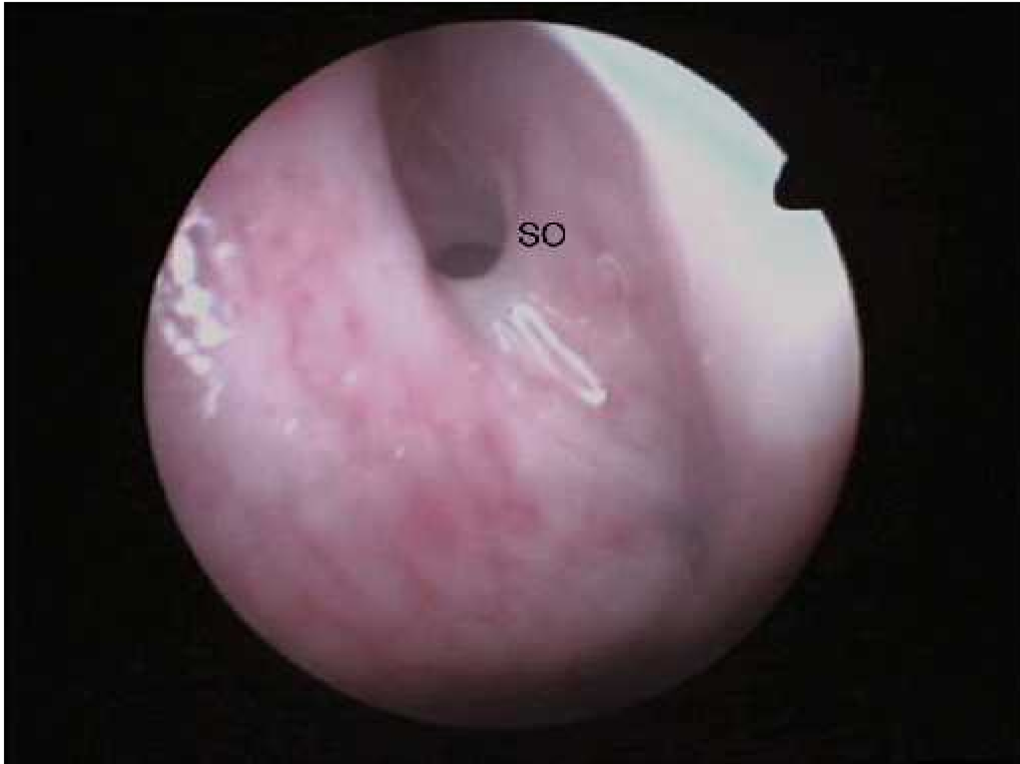

Fig. 9

An round sphenoid ostium (SO)

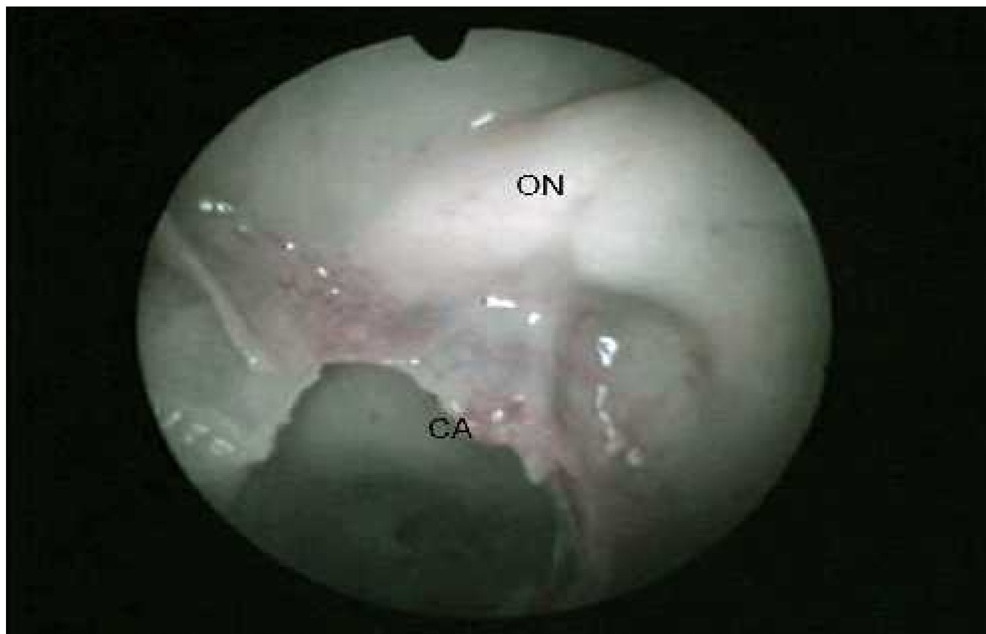

Fig. 10

Endoscopic view showing Optic (ON) and Carotid (CA) bulge.

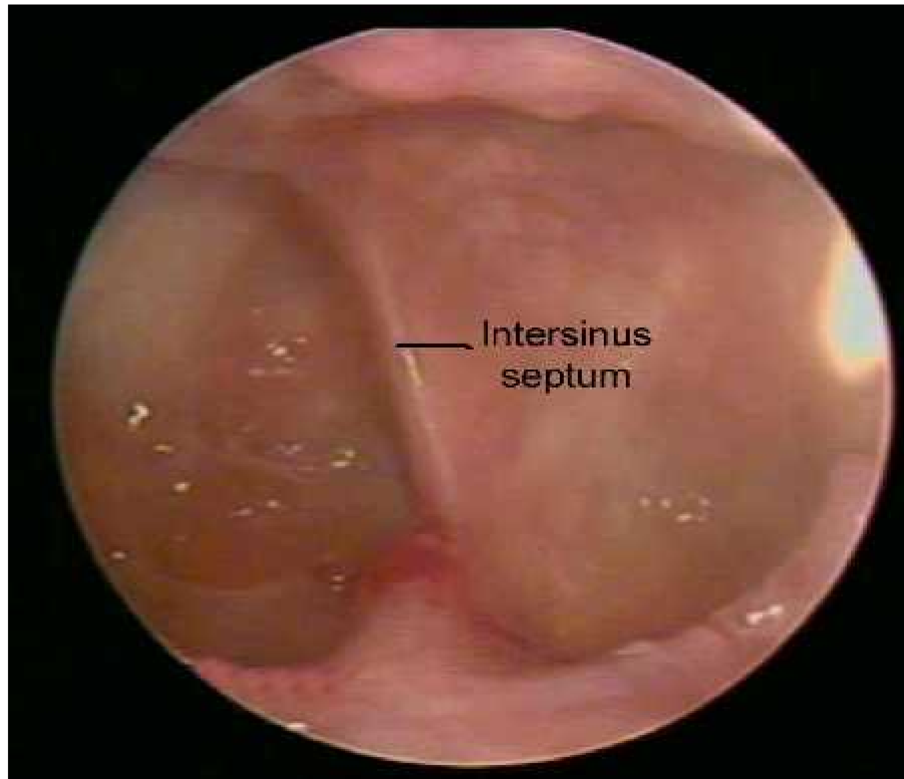

Fig. 11

Post-operative view showing position of inter-sinus septum

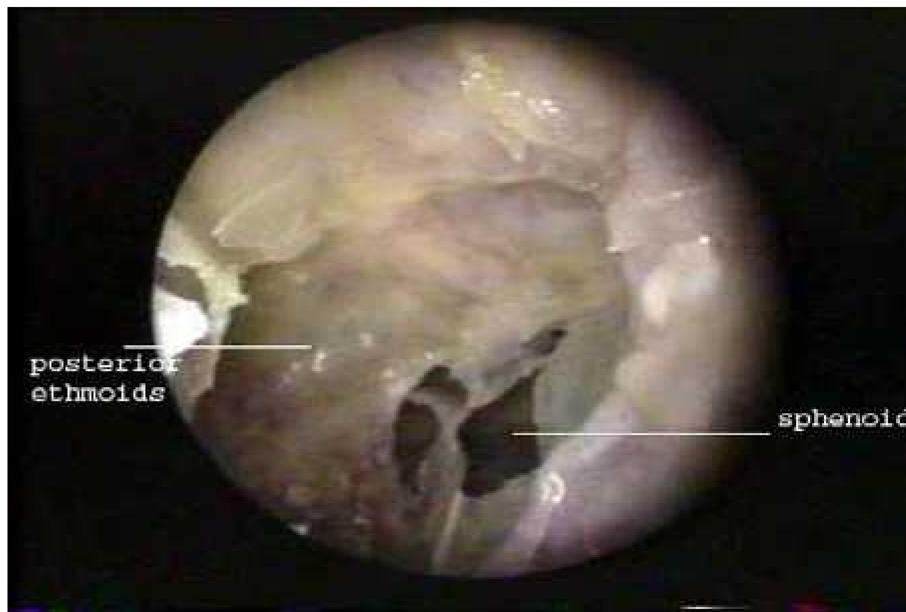

Fig. 12

Relation of posterior ethmoids to sphenoid

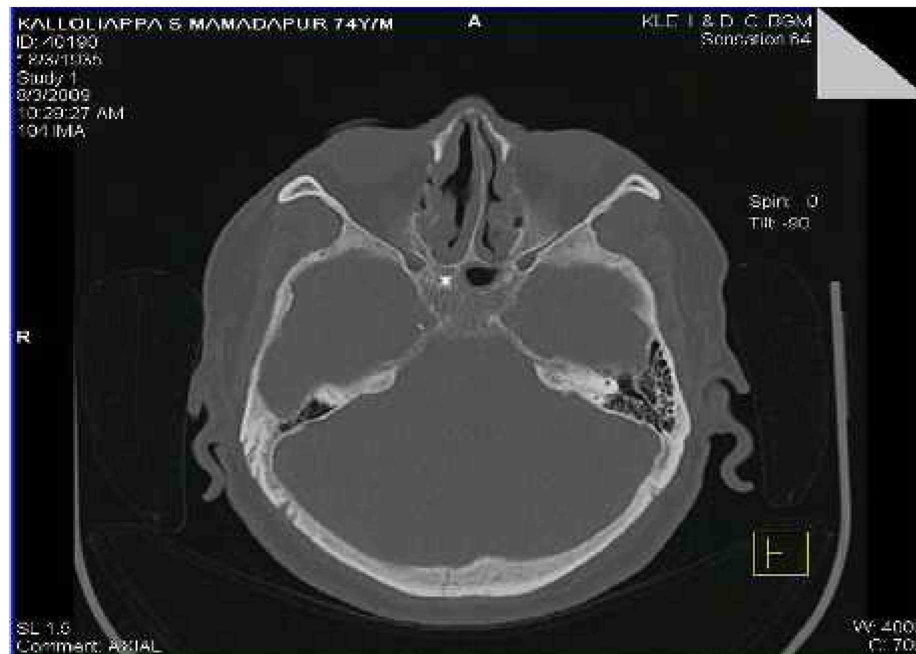

Fig. 13

CT scan showing right conchal (*) type of pneumatization

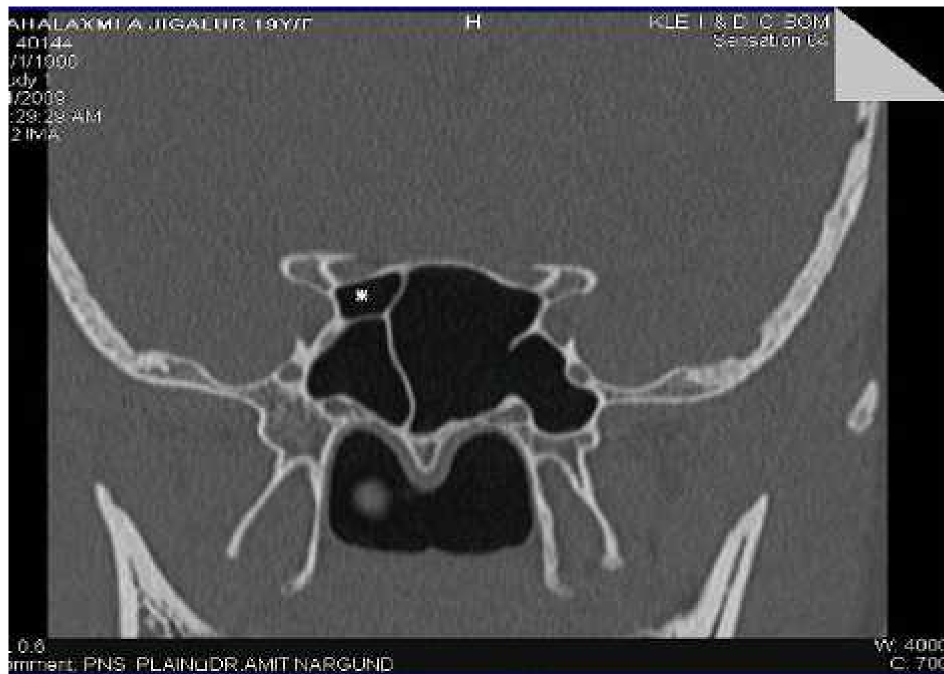

Fig. 14

CT scan showing left sphenoid dominance and Onodi cell (*)

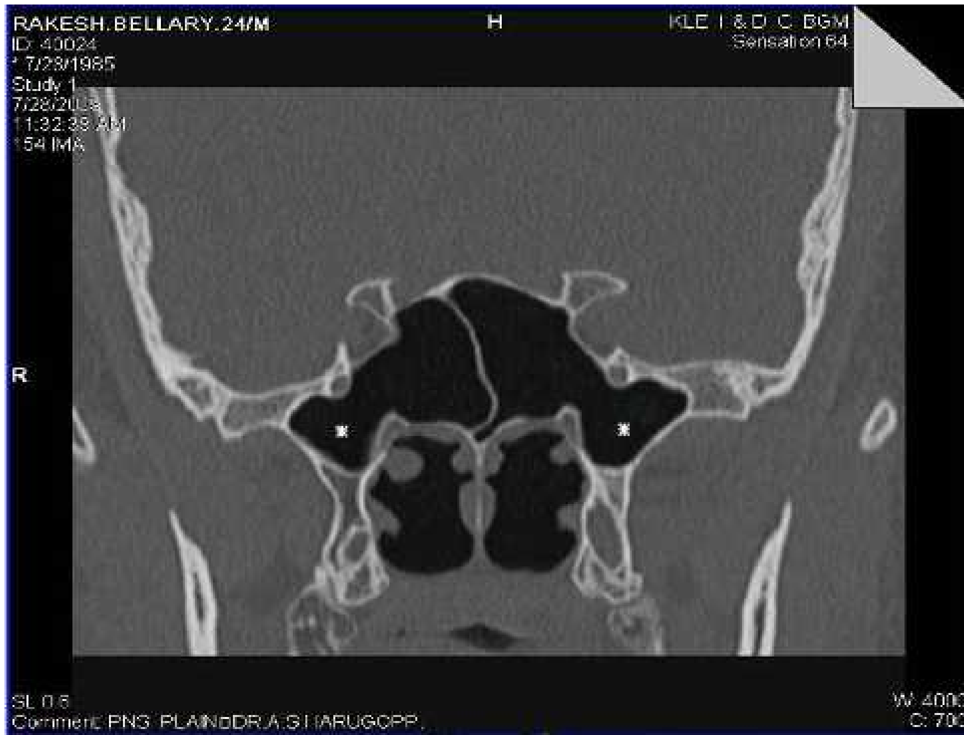

Fig. 15

CT scan showing pneumatized pterygoid process (*)

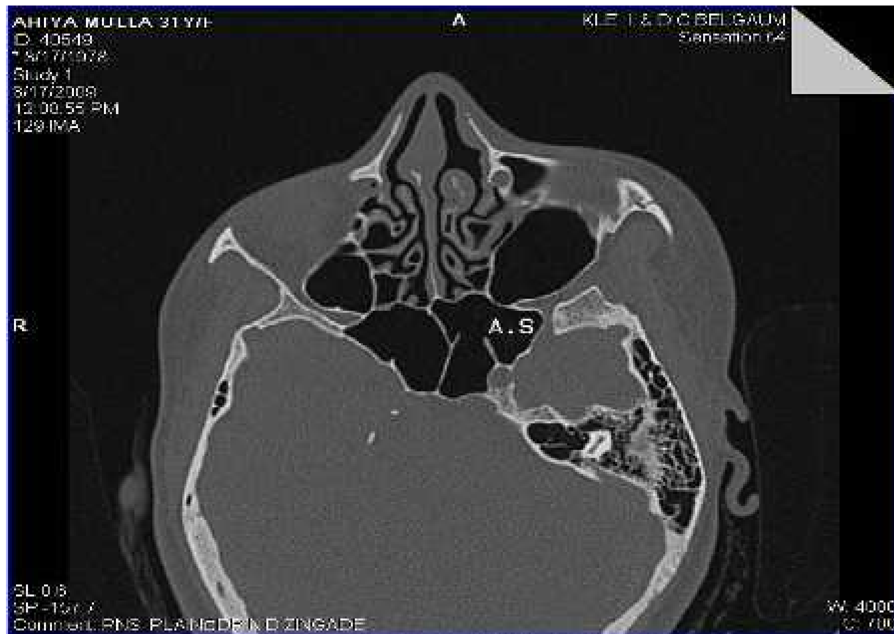

Fig. 16

CT scan showing accessory septum (AS) ending on internal carotid artery

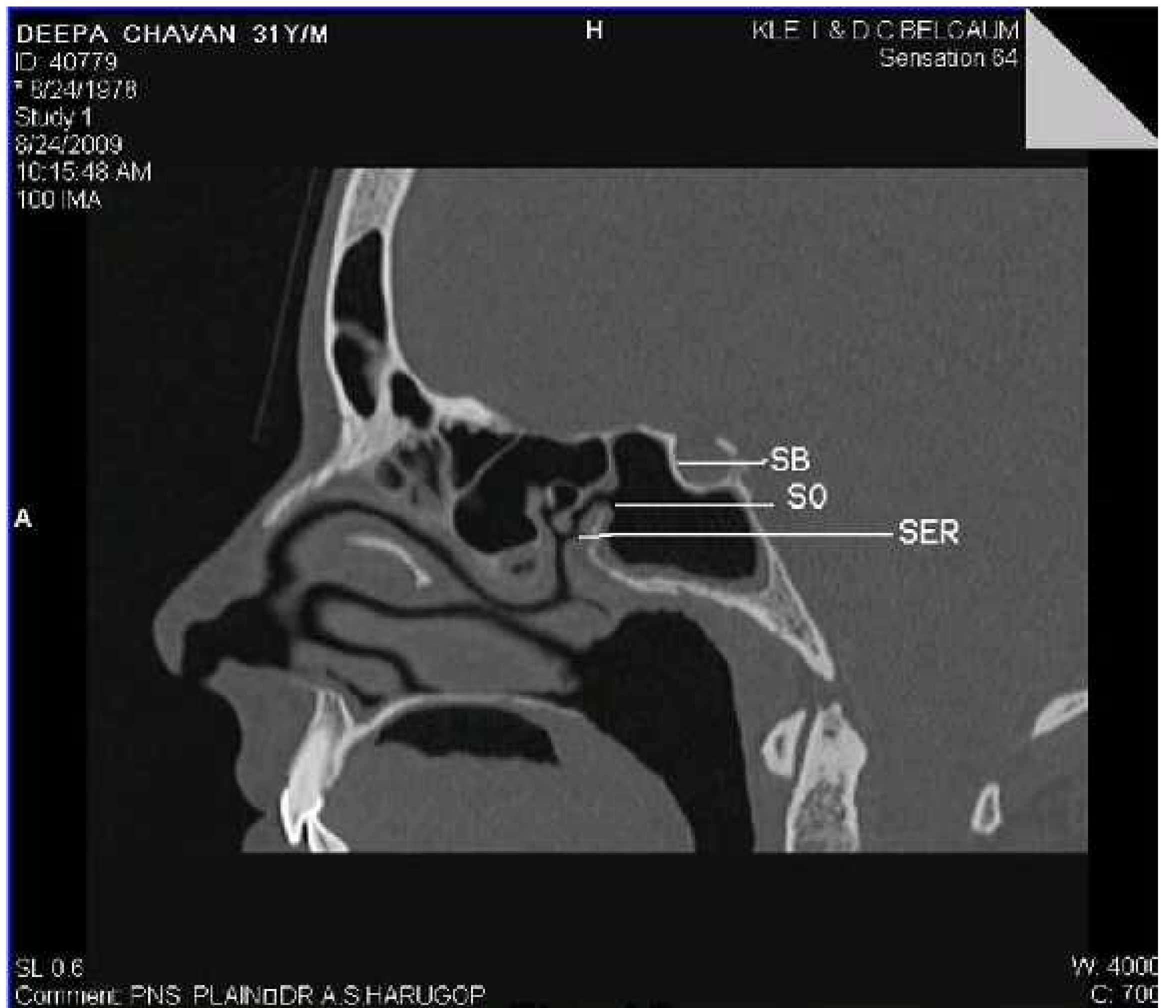

Fig. 17

CT scan showing sellar bulge (SB), sphenoid ostium

(SO), spheno-ethmoid recess (SER).

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MASTER CHART FOR FINDINGS IN CADAVERS

Sr. No.	Sex	Pneumatization			Shape of SO		Termination of ISS		Dominance		Dimensions (cm)						Volume (ml)	Accessory Septa		Termination of Septae			Protrusion of	
											AP		Transverse		Vertical									
		Pre-sellar	Sellar	Post-sellar	R	L	ICA	ON	R	L	R	L	R	L	R	L		Single	Multiple	ICA	ON	ISS	ICA	ON
1	M	✓			r	r			✓		1.6	1.3	1.3	1.5	1.3	1.1	2.5							
2	M			✓	r	o	✓		✓		3.1	2.9	1.9	1.8	2.5	2.6	8.9	✓		✓			✓	✓
3	M			✓	r	o			✓		3.2	2.7	1.8	1.6	2.4	2.7	8.7							
4	F		✓		r	r				✓	1.7	2.1	1.4	1.9	2.0	2.4	8.2							
5	M			✓	o	o			✓		3.1	2.9	3.2	2.9	2.3	2.5	9.1	✓		✓			✓	✓
6	M			✓	r	r	✓				3.1	2.9	1.9	1.7	2.4	2.5	8.9						✓	✓
7	M			✓	o	o			✓		2.9	2.6	2.1	1.8	2.6	2.4	8.8							
8	M			✓	r	o			✓		2.6	2.5	2.2	2.1	2.6	2.2	8.6	✓		✓				
9	M			✓	r	o					2.5	2.7	2.1	1.9	2.7	2.0	8.7							
10	M			✓	o	r	✓			✓	2.2	2.5	1.8	2.1	1.8	2.2	8.8	✓			✓			
11	M			✓	r	r		✓	✓		3.6	3.1	2.1	1.9	2.5	2.3	8.5							
12	M			✓	r	o			✓		3.7	3.0	2.2	1.7	2.6	2.4	8.7	✓		✓				
13	M			✓	r	o	✓		✓		3.7	3.4	2.3	2.2	2.7	2.5	9.2						✓	✓
14	M			✓	o	o				✓	2.1	2.4	1.9	2.1	1.8	2.3	9.1	✓				✓		✓
15	F	✓			o	r			✓		1.5	1.6	1.8	1.7	1.9	1.4	2.7		✓			✓		
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17	M	✓			r	o	✓		✓		1.4	1.2	1.3	0.8	1.5	1.1	2.8							
18	M			✓	o	o				✓	2.3	2.6	1.7	2.2	1.9	2.3	9.4		✓			✓	✓	✓
19	M		✓		r	r					1.9	2.2	1.2	1.5	1.7	2.1	8.1	✓		✓			✓	
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30	M	✓			o	r	✓				1.4	1.6	1.1	1.3	1.4	1.2	2.6							

MASTER CHART FOR CT SCAN FINDINGS

Sr. No.	Sex	Pneumatization			Dominance		Dimensions (cm)						Accessory Septa		Termination of Accesory Septa			Protrusion of			Onodi Cells	ISS	
							AP		Transverse		Vertical												
		Pre-sellar	Sellar	Post-sellar	R	L	R	L	R	L	R	L	R	L	ICA	ON	Others	ICA	ON	Other		ICA	ON
1	F			GWS ✓	✓		3.5	3.5	2.8	2.6	1.9	2.3	✪✓										
2	F			✓	✓		3.6	3.6	2.9	2.7	2.0	2.4											
3	M	✓			✓		2.2	1.8	1.3	1.5	1.9	1.6	✓				LW	✓				✓	
4	F			✓	✓		3.2	3.1	1.5	1.9	2.7	1.9		✓			LW	✓			✓		
5	M	✓			✓		2.1	1.7	1.4	1.4	1.8	1.5											
6	M			PP ✓	✓		3.5	3.3	2.8	2.3	2.7	2.6	✪✓		✓			✓					
7	M			✓	✓		3.6	3.3	2.9	2.4	2.8	2.7											✓
8	F			✓	✓		3.3	3.2	1.6	2.0	2.8	2.0	✓				LW	✓					
9	F	R ✓	L ✓			✓	1.7	2.4	0.9	1.5	1.9	1.9										✓	
10	F		✓			✓	1.8	2.3	0.8	1.7	1.8	2.0										✓	
11	F			* ✓		✓	2.5	3.0	2.3	2.8	2.7	2.8	✓	✪✓	✓	✓	LW	✓	✓	VN, MN			
12	M	L ✓	R ✓		✓		2.6	1.3	2.3	1.4	2.4	1.7										✓	
13	M	✓			✓		2.5	1.4	2.3	1.3	2.3	1.5											
14	F			Ω✓		✓	2.7	3.1	2.4	2.9	2.8	2.7	✓	✓	✓			✓	✓	VN		✓	
15	F			✓	✓		2.9	2.1	2.8	1.4	2.8	2.5	✪✓		✓		LW			MN			
16	M	L ✓				✓	-	0.7	-	1.1	-	1.2											
17	F			✓	✓		3.0	2.3	2.6	1.5	2.9	2.6	✪✓				LW	✓					
18	M		✓			✓	2.6	2.8	2.1	2.3	2.2	2.4											
19	M			PP ✓		✓	2.8	2.2	2.8	2.2	2.4	2.9						✓		VN, MN		✓	
20	F		✓		✓		2.7	2.1	2.1	1.7	1.8	1.7											
21	M			✓		✓	2.7	2.4	2.5	2.8	2.3	2.8											
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23	M		L ✓		✓		2.8	1.5	1.8	1.1	2.4	1.5											
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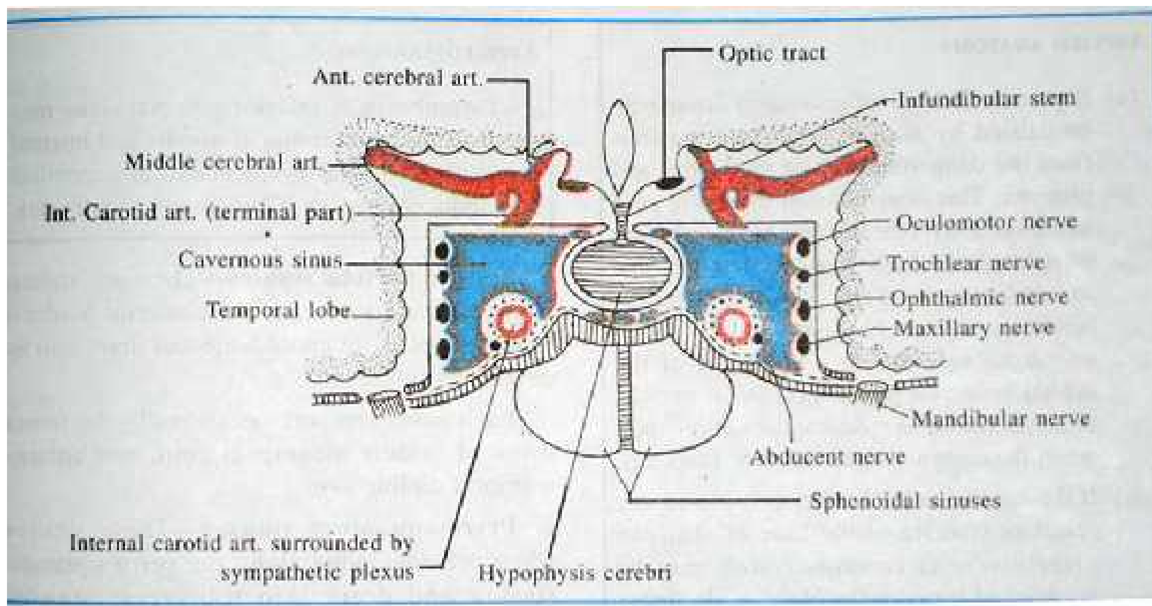

Fig. 1

Relations of sphenoid sinus

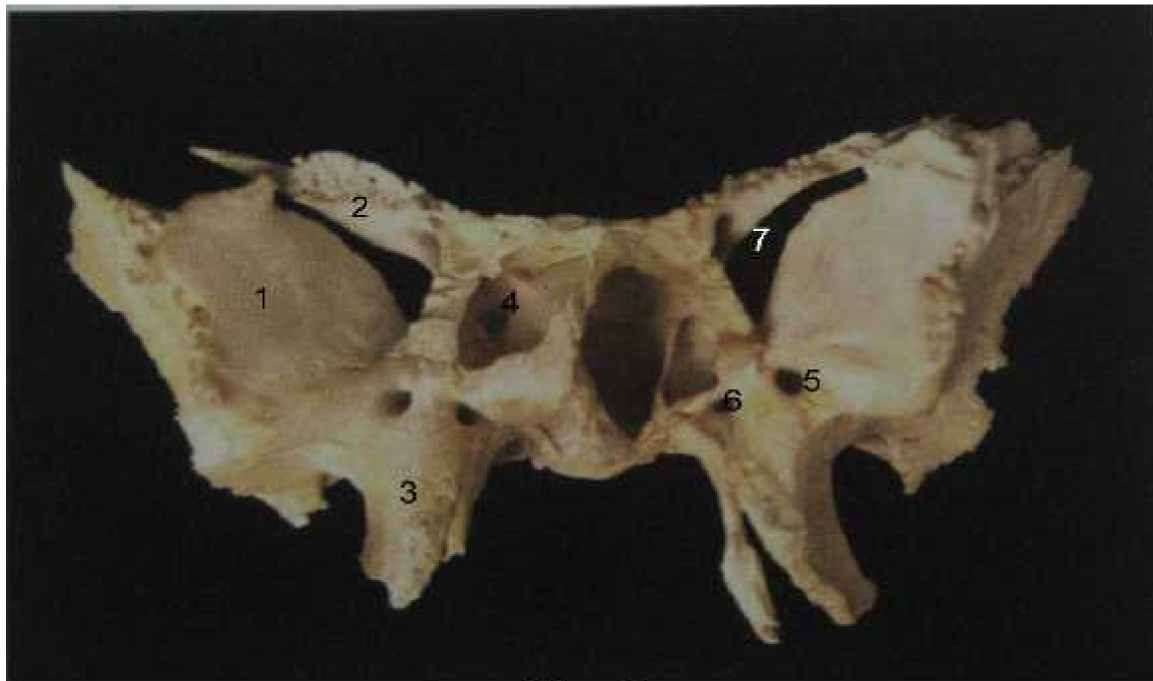

Fig. 2

Sphenoid bone showing 1)Greater wing; 2)Lesser wing; 3)Pterygoid process; 4)Sphenoid sinus; 5)Foramen rotundum; 6)Pterygoid canal; 7)Superior orbital fissure.

Fig. 3

Post-sellar sinus with pituitary bulge (P.B.)

Fig. 4

Post-sellar sinus with accessory septum (A. S.)

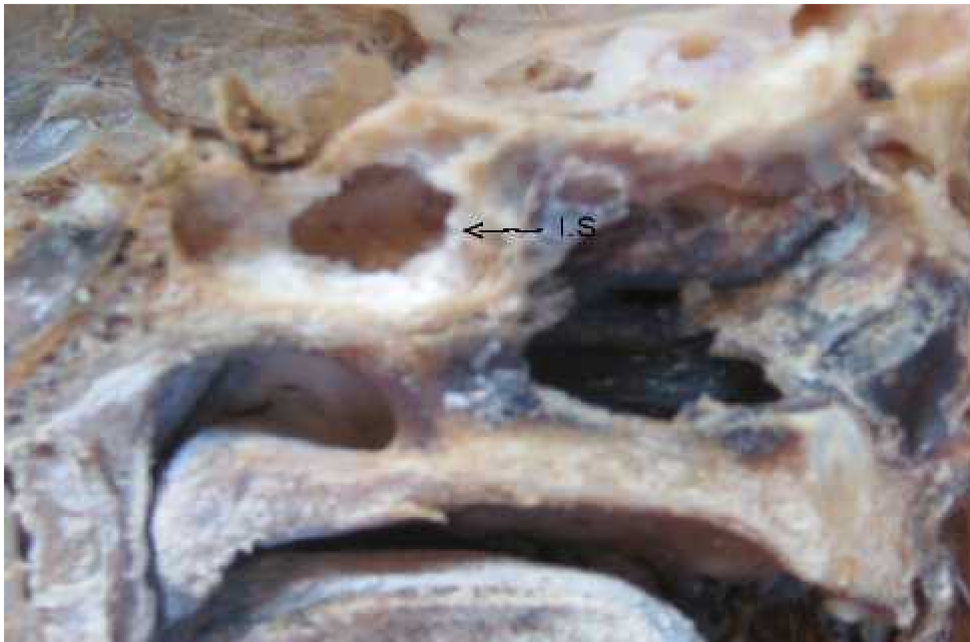

Fig. 5

Sphenoid sinus showing inter-sinus septum

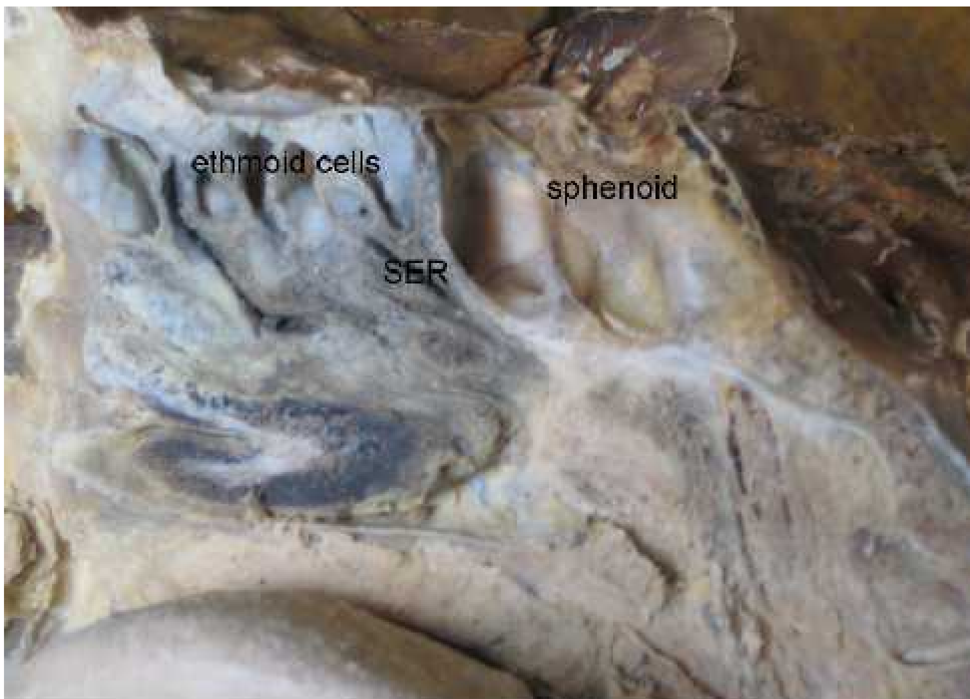

Fig. 6

Relations of sphenoid sinus and spheno-ethmoid recess (SER)

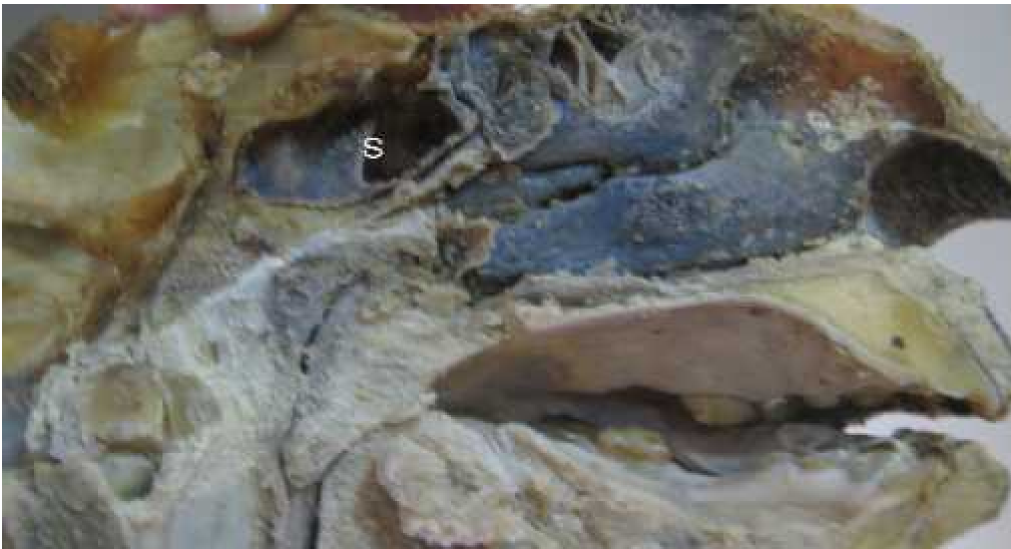

Fig. 7

Figure showing right sphenoid (S) dominance

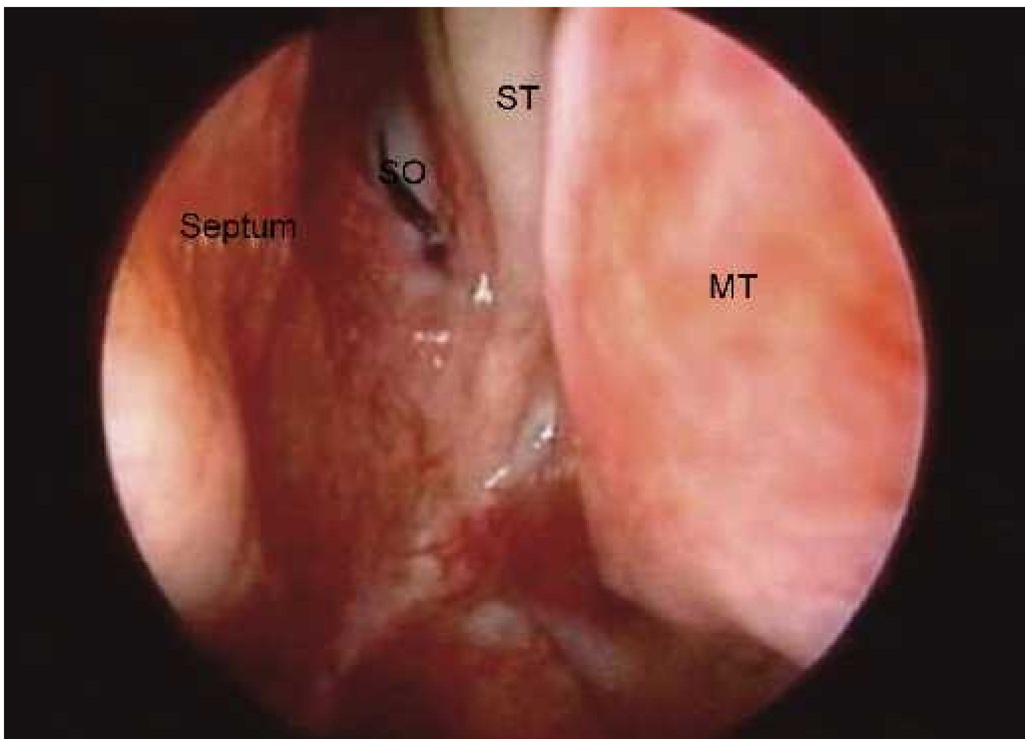

Fig. 8

An oval sphenoid ostium (SO), MT- middle turbinate, ST- superior turbinate.

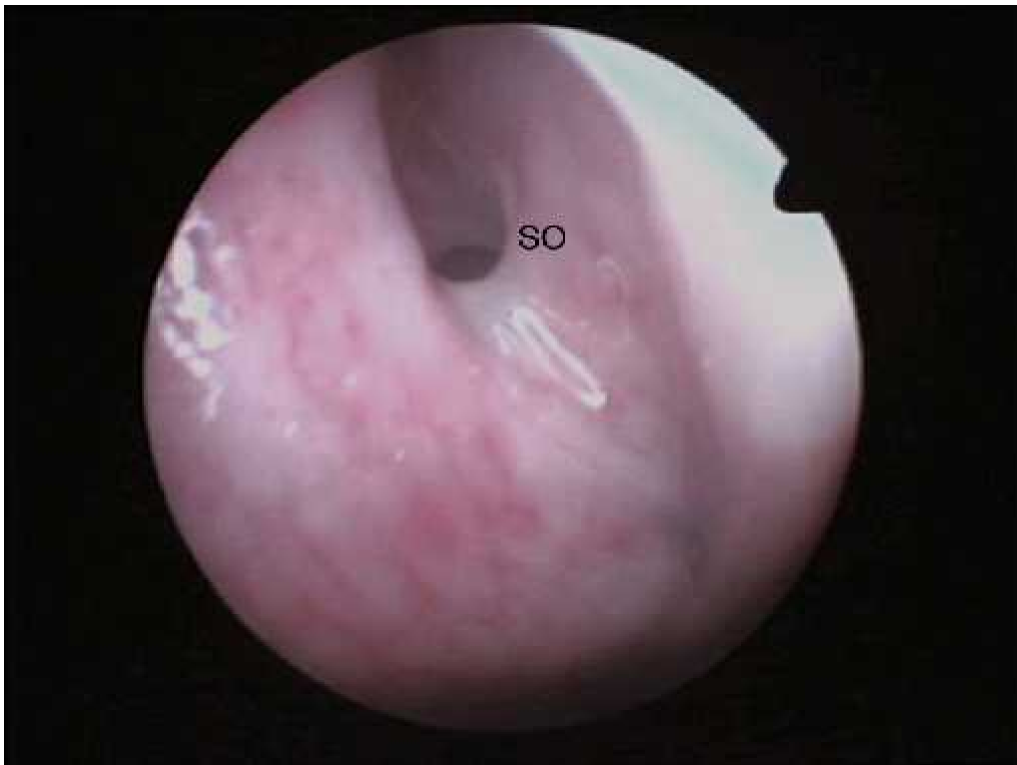

Fig. 9

An round sphenoid ostium (SO)

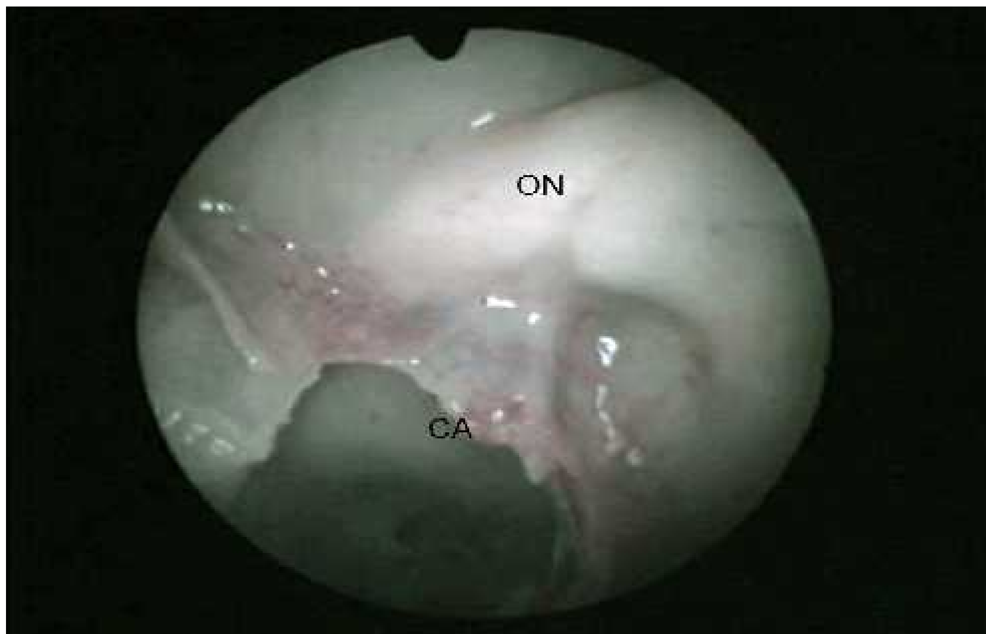

Fig. 10

Endoscopic view showing Optic (ON) and Carotid (CA) bulge.

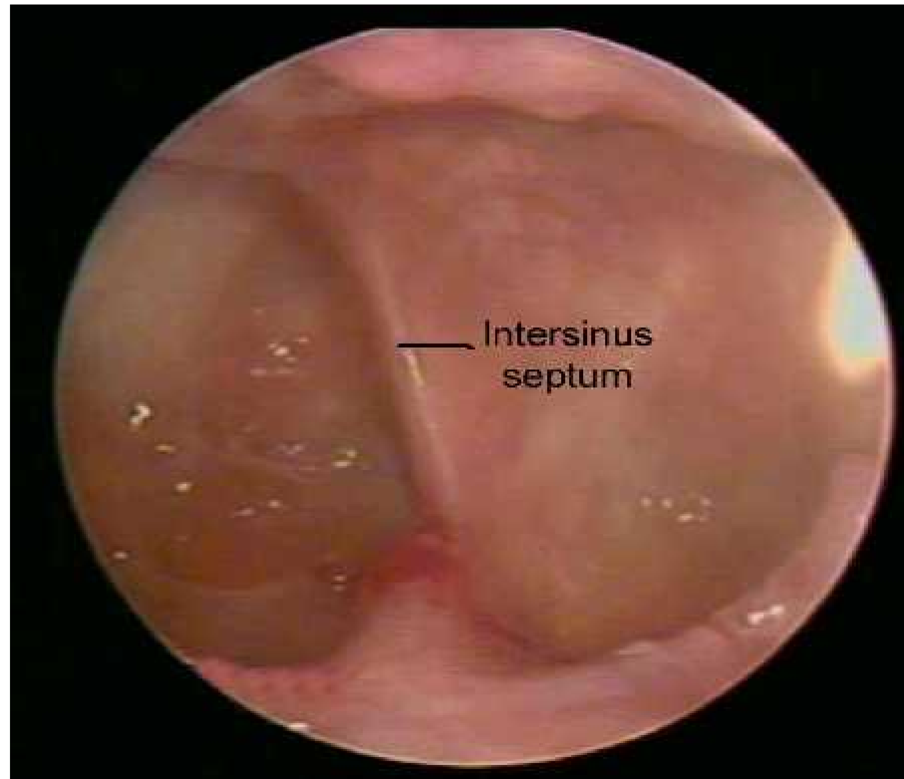

Fig. 11

Post-operative view showing position of inter-sinus septum

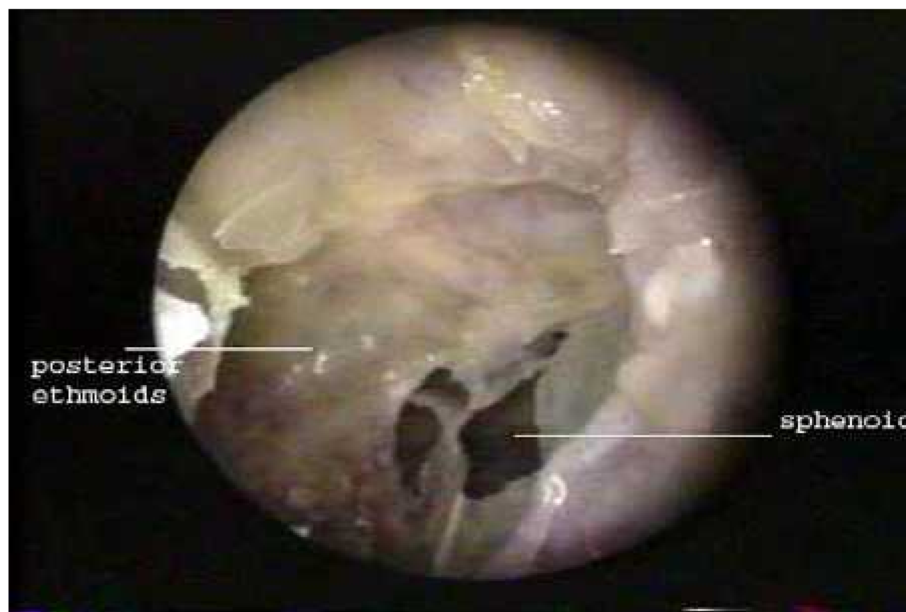

Fig. 12

Relation of posterior ethmoids to sphenoid

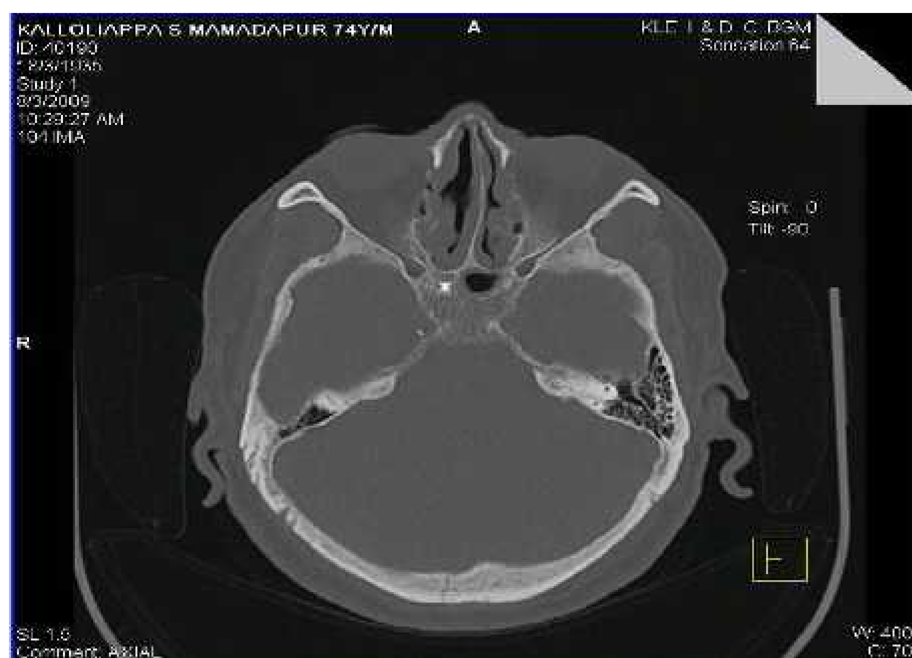

Fig. 13

CT scan showing right conchal (*) type of pneumatization

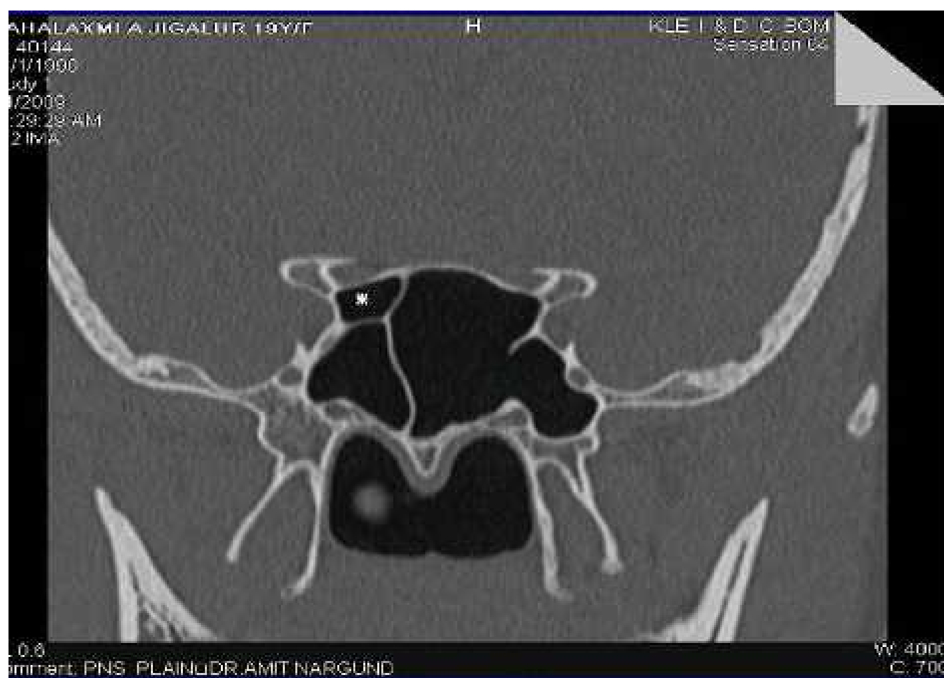

Fig. 14

CT scan showing left sphenoid dominance and Onodi cell (*)

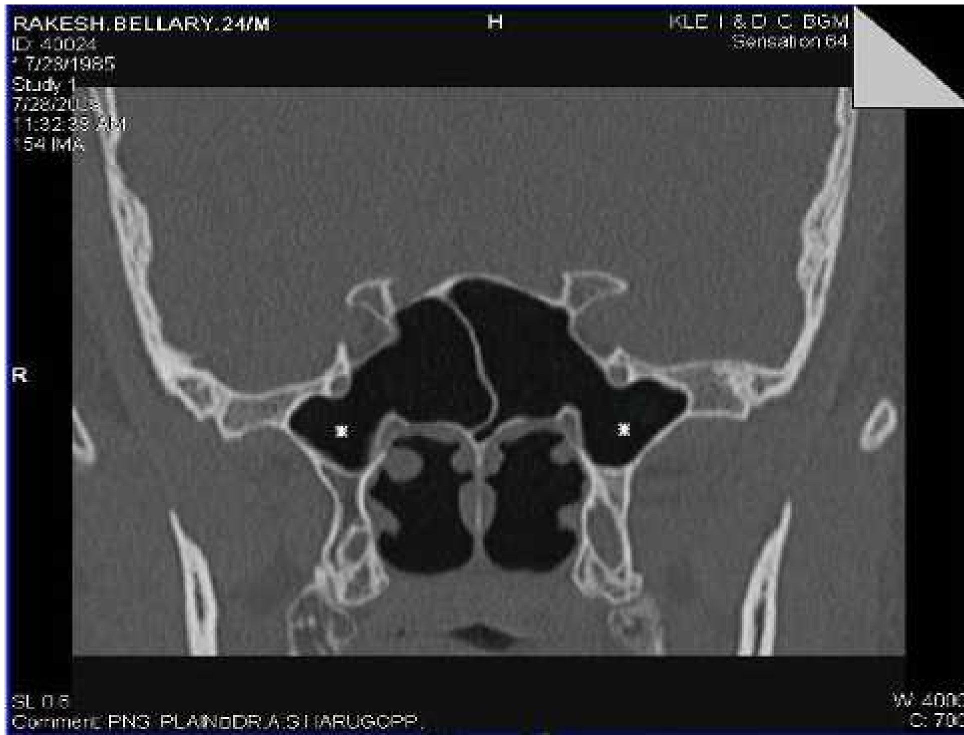

Fig. 15

CT scan showing pneumatized pterygoid process (*)

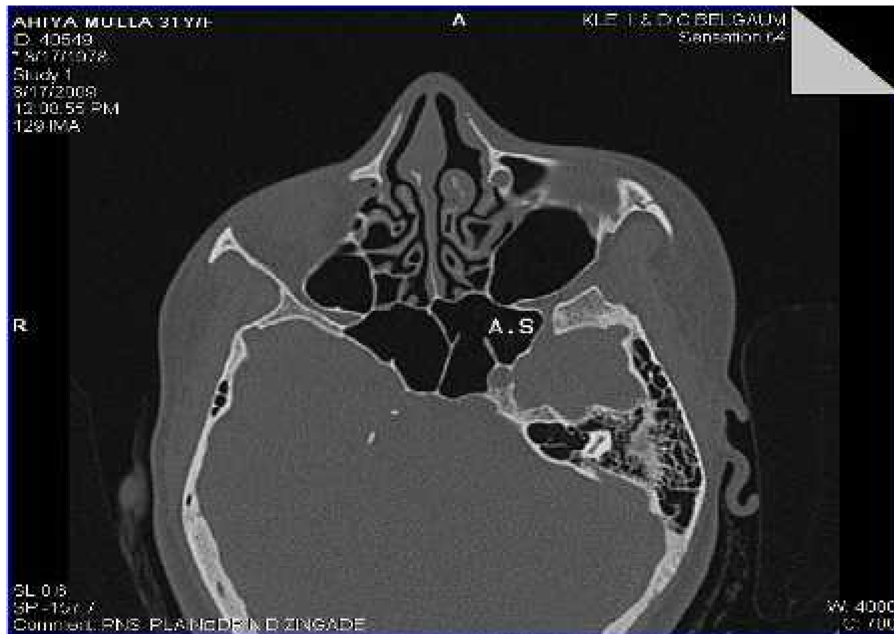

Fig. 16

CT scan showing accessory septum (AS) ending on internal carotid artery

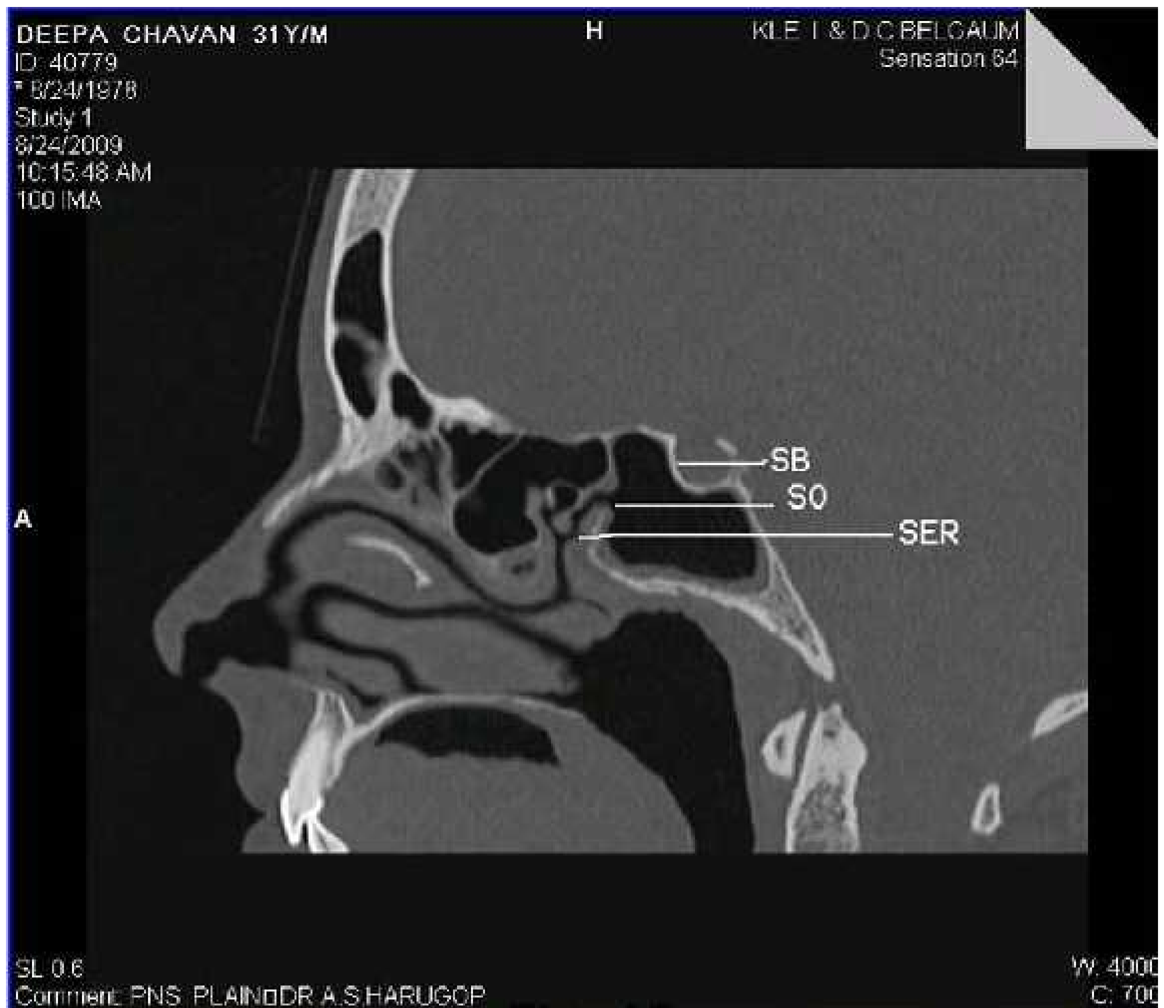

Fig. 17

CT scan showing sellar bulge (SB), sphenoid ostium

(SO), spheno-ethmoid recess (SER).

RESEARCH PARTICIPATION INFORMATION AND CONSENT FORM

Objective/ Purpose and Procedure of the study –

It is intended to study anatomy of sphenoid sinus and its important relations by endoscopy or CT scan. The study will involve the parameters of sphenoid sinus of those subjects who are undergoing Endoscopic Sinus Surgery excluding patients with sphenoid sinusitis. It will include study of CT scans of those subjects who would be undergoing CT scan Brain and are not suffering from sinusitis.

Risks and Benefits –

Surgical risk is being explained by ENT surgeons. Side effects of radiological exposure in patients undergoing CT scan of Brain are minimal. Exposure to pelvis and abdomen is minimized by using lead apron. Subjects will not get any benefit by participation in this study.

Alternative –

Participation in this study is entirely voluntary and subject may withdraw from the study at any time. Information of new literature regarding the subject of study, will be provided from time to time.

Privacy and Confidentiality –

All information/ findings being collected about the subject will be kept confidential and his/ her identity will not be revealed.

Institutional/ Sponsors policy -

NA.

Financial Incentives For Participation –

There is no commitment for compensation to the participants. No cost will be incurred by them for this study.

Authorization to Publish the Results –

We are authorized to publish the results of the study without revealing the identity of the participants.

____

Signature of P. G. Student

Consent Statement

I hereby volunteer to participate in this study. The information in the consent form has been explained to me in language which is understood by me. It has been explained to me that I can withdraw from study at any time. I was given adequate time to clear my doubts and to know my rights as study participant. I can contact investigators of this study regarding any doubt about study participation.

Signature or Left Thumb Print of Participant or Legally Authorized Representative:

Participant's Name Signature/ Thumb Print

Experimenter's Name Signature

Witness Name Signature/ Thumb Print

Date