ANATOMICAL VARIATIONS OF NASAL CAVITY AND PARANASAL SINUSES IN SINUSITIS ON CT-SCAN

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A thesis submitted in fulfilment of the requirements for the award of the degree of Master of Philosophy (Anatomy)

Department of Anatomy

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Specially dedicated to

my loving and caring father,

mother, siblings,

and my supervisor

Prof. Dr. Ambreen Usmani.

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ABSTRACT

Enhancements in functional endoscopic sinus surgery (FESS) and computed tomography (CT) scans have concomitantly amplified interest in variation of the nasal cavity and paranasal sinus (PNS) region anatomy. Anatomical variations are normal morphological structures that are present in humans. The presence of these anatomical variations can affect nearby anatomical relations resulting in structural changes. By the vast range of anatomical variations in nasal cavity and paranasal sinuses, every case of sinusitis must be planned carefully to avoid complications in surgical procedures. Certain anatomical variants are supposed to be a causative factor for development of sinus pathology and hence it should be compulsory for the radiologist to be aware of the anatomical variants of nasal cavity and PNS especially if the subject is considered for surgical intervention. CT Scan imaging of nose and PNS is mandatory in patients with history of sinusitis in order to evaluate the detailed anatomy which includes normal morphology, anatomical variations, bony details and the extent of the disease pathology. The objectives of this study were to determine the incidence of sinonasal anatomic variants in symptomatic subjects of sinusitis on CT-scan, and to evaluate the association between gender, symptoms and anatomical variations of sinonasal region in symptomatic subjects of sinusitis on CT-scan. A cross-sectional study including 80 subjects was conducted at PNS Shifa Hospital, Karachi between January-June 2020. The study involved males and females with age ranges from 18-60 years. Subjects were prepared for CT Scan of PNS in coronal and axial view. Study included subjects symptomatic for sinusitis irrespective of gender associated with headache, nasal obstruction, facial pain, rhinorrhea and sinus mucosal thickening of greater than 1 mm. The scans were reviewed to study the nasal septum, turbinates, uncinate process, ethmoid air cells, hypoplastic frontal sinus, maxillary septa, asymmetry of sphenoid sinus cavity and all these anatomical variants were correlated with symptoms of sinusitis. The results of this study showed that there were more males (53) as compared to females (27) with mean age of 44.6±18.5 years who were suffering from sinusitis, headache being the most frequent symptom followed by nasal obstruction, rhinorrhea and facial pain with reported frequencies of (48.75%), (26.25%), (18.75%) and (6.25%) respectively. The anatomical variations were prevalent as 100% in

symptomatic subjects of sinusitis with significant number found in male gender. The most frequent anatomical variants were deviated nasal septum (DNS) (58.5%) followed by agger nasi cells (56.3%), concha bullosa (CB) (46.3), septal bony spur (40%), hypoplastic frontal sinus (31.3%), asymmetry of both cavities of the sphenoid sinus (18.8%), onodi cells (12.5%), haller cells (11.3%), uncinate process deviation (2.5%) and pneumatization (3.8%), superior CB (1.3%), paradoxical middle CB (1.3%), and maxillary septa (1.3%). It was noticed that only nasal obstruction and headache were associated with agger nasi cells right and left sides both with significant p-values of 0.014 and 0.026 respectively. Moreover, insignificant association was found between gender, anatomical variants and symptoms of sinusitis.

Key words:

Anatomical Variations, Paranasal Sinuses (PNS), Nasal cavity, sinonasal region, CT Scan, Functional Endoscopic Sinus Surgery (FESS).

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LIST OF ABBREVIATIONS

AS	-	Additional septum
CSF	-	Cerebrospinal fluid
CN II	-	Cranial nerve II- Optic nerve
CT	-	Computed tomography
CB	-	Concha bullosa
DNS	-	Deviated nasal septum
ENT	-	Ear, Nose, and Throat
FESS	-	Functional Endoscopic Sinus Surgery
MRI	-	Magnetic Resonance Imaging
MS	-	Middle Septum
MT	-	Middle Turbinate
OMC	-	Osteo-meatal complex
PNS	-	Paranasal sinuses
SPSS	-	Statistical Package for Social Science
UP	-	Uncinate Process

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Paranasal sinuses (PNS) were considered as a mysterious area of skull by previous anatomists. The PNS historically, was first recognized within the bones of the skull by ancient Egyptians then later contribution was made by Greek physicians. During Middle Ages, the anatomists Renaissance period-Leonardo da Vinci and Vesalius participated to make further enhancement in the understanding of the complex anatomy of PNS. The Nathaniel Highmore's name was first who defined the maxillary sinus, which is largest sinus of all (Mavrodi & Paraskevas, 2013).

The PNS is an important region of distinct interest for various medical fields including the maxillofacial surgery, and otorhinolaryngology. The PNS, which are carefully concealed inside the skull bones, have repeatedly confused the anatomists and medical experts of the past years. Probably, because the PNS are closely connected to many organs of the body, for example the brain, eyes, nose and mouth, many unusual schemes about their purpose have been established since years. The history of PNS, definitely, commences from the antiquity of the word's "sinus" and "antrum." The term "sinus", is a Latin word which stands for a curve, hollow in land, a bay or gulf, or the innermost part of something (Nall, 1964).

Therefore, clearly, the etymology of the term is associated with the structure of the region. The similar discipline applies also to the word "antrum," which, combined with Highmore's name— "Highmore's antrum"—is ascribed to the maxillary sinus. The word "antrum" is derived from the Greek word "άντρον," which means a hollow in land, cave, or grotto, and even a place inhabited by nymphs or other Greek deities, or a place dedicated to them (Gazi, 1839). The PNS region is subject to a great diversity of lesions. Advancement in invasive surgical procedures such as functional endoscopic sinus surgery (FESS) and instrumentation, use of the imaging tools for instance computed tomography (CT), and understanding the regional anatomy along with anatomical variations have aided to make endoscopic operations with fewer complications in the PNS region. Anatomical variations of sinonasal region are significant as they can be responsible for disease process or difficulty during surgical procedure (Kantarci, Karasen, Alper, Onbas, Okur, & Karaman, 2004; Qureshi & Usmani, 2020).

The nasal cavity and PNS are composed of anatomical complex aggregate of mucosal lined air-filled spaces within the bones of head region. Paranasal sinuses include four paired sinuses which are frontal sinus, ethmoid sinus, sphenoid sinus, and the maxillary sinus is largest of all (Figure 1.1). These air-filled spaces perform various functions which includes warming and humidification of air, olfaction, lightens the weight of the skull, improves the quality of voice, absorbing traumatic forces and aiding in immune defense. Understanding of anatomy of sinonasal region is critical and it has very important role in surgical procedures especially FESS (Hwang & Abdolkhani, 2009).

There are three bulbous projections present in lateral nasal wall, that is the superior, middle, and inferior turbinates (conchae) (Figure 1.1). These three projections divide the nasal cavity into three meati, which are superior meatus, middle meatus, and inferior meatus. The superior meatus receives posterior ethmoid air cells and sphenoid sinus via spheno-ethmoidal recess. The middle nasal meatus drains frontal sinus by nasofrontal recess, maxillary sinus through the maxillary ostium, and the anterior ethmoid air cells by ostia of ethmoid cell. And in inferior meatus the nasolacrimal duct drains (Reddy & Dev, 2012).

The PNS form a complex variable unit of four paired air-filled spaces at the opening of the proximal airway of the body. The development of PNS starts from furrows and ridges in the lateral wall of nasal cavity during 8th week of development, and sinuses continue their formation as air cells within the cavities until early adulthood from the age of 20 to 25 years. Each sinus is named according to the skull bone in which they are located (Arshad, Begum, & Kumar, 2018). Radiologic evidence of various sinuses appears by the age of 4-5 months after birth (maxillary sinus), 1 year of age (ethmoid sinus), 6 years of age (frontal), and 4 years of age (sphenoid) (Dhingra, 2014).

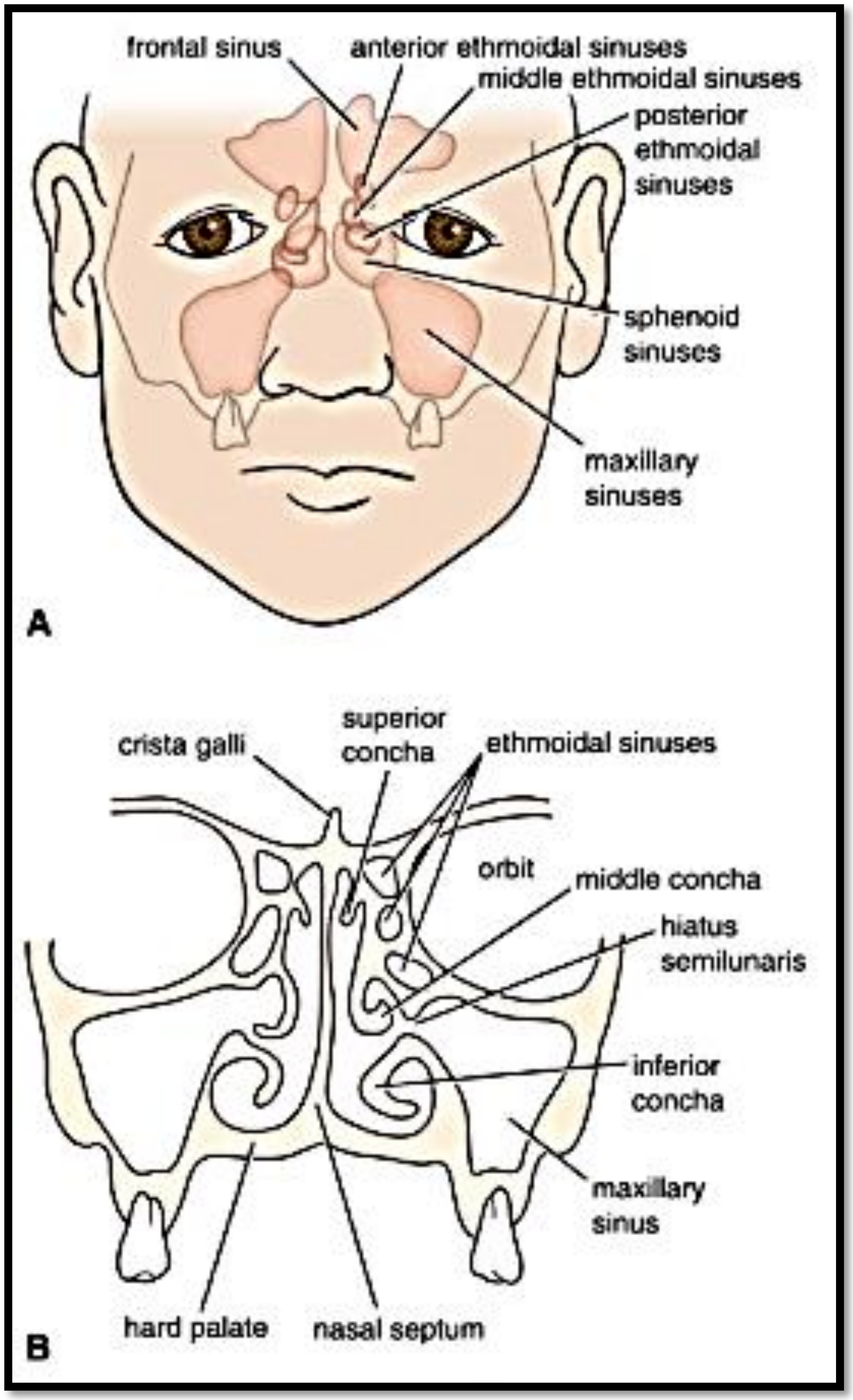


Figure 1.1 A: Paranasal sinuses. B: Coronal section through nasal cavity (Richard, 2018)

1.1.1 Developmental morphology of sino-nasal region

1.1.1.1 External Aspect of the nose

In the 4th week of fetal life, the nose is developed from frontonasal process along with the maxillary and mandibular processes, and it is one of the three facial outgrowths visible during this period of development and in 5th embryonic week. The ectodermal plaques develop on the lateral aspects of the frontonasal process and becomes paired nasal placodes, which are precursors of nares. By day 34, these convex placodes develop into concave nasal grooves and the medial and lateral sides of the nasal placodes begin to protrude forward to become medial and lateral nasal processes (Figure 1.2). The nasal placodes then develop into nasal grooves and eventually become blind-ending nasal pits by 7th week of fetal life. The maxillary process also grows forward and downward. The medial and lateral ridges of the nasal placode lead to the development of the medial and lateral nasal processes, which ultimately contribute to formation of the nares and nasal septum (Hwang & Abdolkhani, 2009). The summary of the embryonic precursors to the facial structures is given in Table 1.1.

1.1.1.2 Nasal cavity

During fetal intrauterine life in 5 to 7 weeks, the nasal pits deepens to form nasal sac, which is the pioneer of nasal cavity. An epithelial lining called oronasal membrane which is present at posterior border of the nasal cavity, it abuts the oropharyngeal cavity. This membrane ruptures during 42-44 day of fetal life and creates a communication between two cavities which are nasal and oral cavities. A cartilaginous structure which is nasal capsule encases the nasal cavity, forming boundary to sino-nasal region. The nasal capsule is a mesodermal structure formed in third month of intrauterine life in which chondrification and ossification begins shortly thereafter. Prior to bone formation rudimentary nasal cavity can be seen (Hwang & Abdolkhani, 2009).

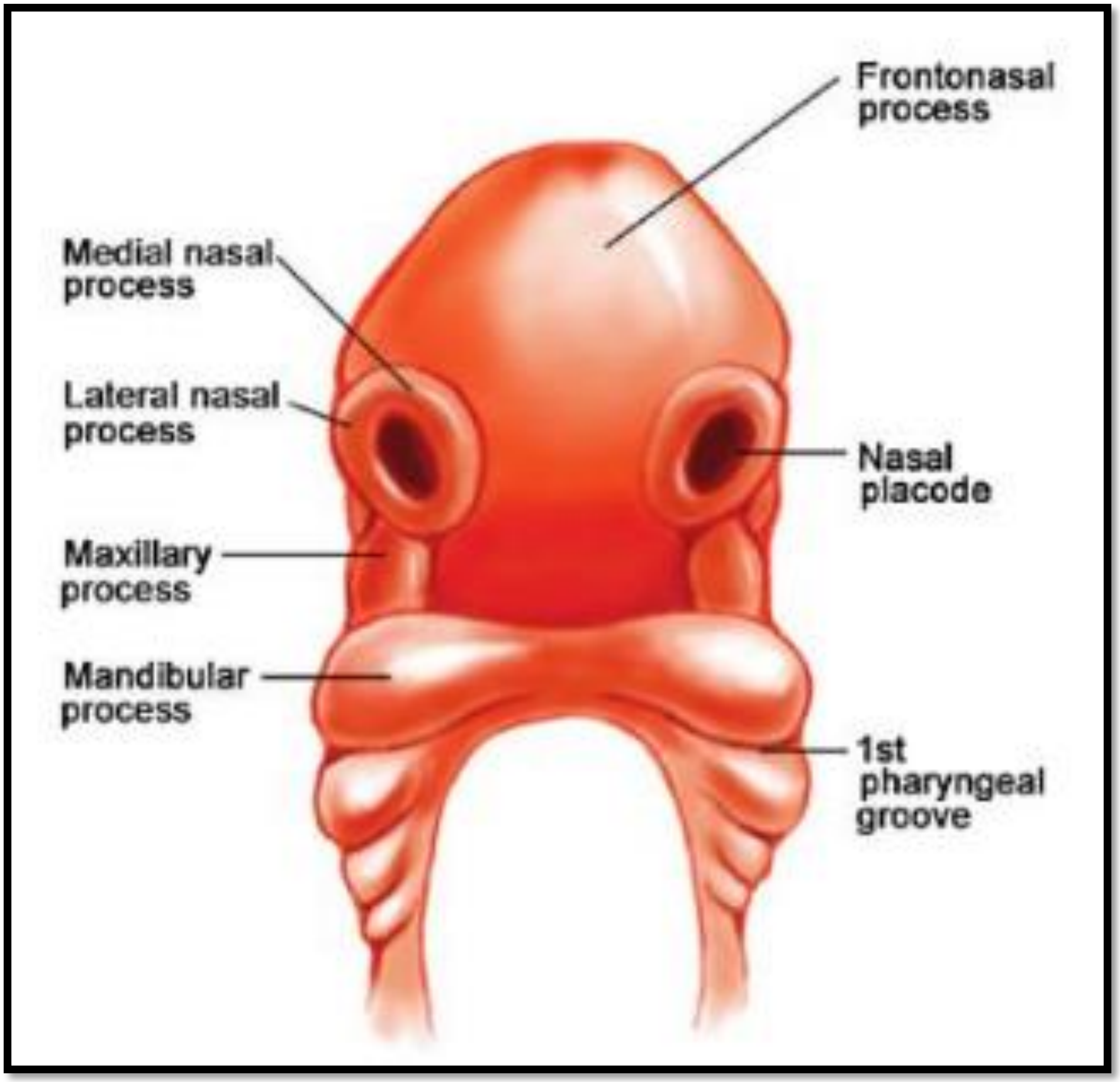


Figure 1.2 The frontonasal, maxillary, and mandibular processes can be appreciated. The nasal placode, which later develops into nasal pit can be seen within the medial and lateral nasal processes (Hwang & Abdolkhani, 2009)

Table:1.1 Summary of the embryonic precursors to the facial structures (Hwang & Abdolkhani, 2009)

Summary of the embryonic precursors to the facial structures		
Embryonic precursor	**Soft tissue correlate**	**Skeletal correlate**
Frontonasal process	Bridge of nose	Nasal bones
Medial nasal process	Columella and philtrum	Perpendicular plate of ethmoid and vomer
Lateral nasal process	Nasal sidewall, ala of the nose	-
Maxillary process	Upper lip and cheek	Maxilla, zygoma and secondary plate
Mandibular process	Lower lip and cheek	Mandible
Nasal pit	-	Nasal cavity

1.1.1.3 Lateral nasal wall

The lateral wall of nasal capsule begins to form a series of ridges of mesenchymal origin, superior to palatal shelves during 7^{th} and 8^{th} week of intrauterine life. In 7^{th} intrauterine week, the first ridge which is maxilloturbinal ridge is formed which is the precursor of inferior turbinate. Remaining 5-6 ethmoturbinal ridges develop during 8^{th} week of fetal life and the first ethmoturbinal ridge is sometimes referred as nasoturbinal whose ascending portion gives rise to the agger nasi cell and its descending portion gives rise to uncinate process, remainder of first ethmoturbinal regresses. The second and third ethmoturbinal ridges give rise to middle and superior turbinate respectively, whereas fourth and fifth ethmoturbinal ridges regresses but in some individual it may persist and fuse to form supreme turbinate. The anatomic correlates of ethmoturbinal have lamellar attachments to the lateral nasal wall which are used as important landmarks during sinus surgery especially in FESS, which are summarized in Table 1.2. The development of ethmoturbinals is followed by development of PNS (Hwang & Abdolkhani, 2009).

1.1.1.4 Paranasal sinuses (PNS)

There are four pairs of paranasal sinuses (PNS) namely, maxillary, frontal, ethmoid and sphenoid sinuses. The maxillary, ethmoid and frontal sinuses develops from evaginations of lateral nasal wall whereas sphenoid sinus arise from an evagination of posterior nasal capsule. In third fetal month sinuses begin to develop, out of which only two sinuses are present at birth namely ethmoid and maxillary sinus. The embryonic origin, volume, blood supply and nerve supply of PNS is summarized in Table 1.3.

Table:1.2 Summary of the lamellar attachments to the lateral nasal wall (Hwang & Abdolkhani, 2009)

Lamellar attachment to lateral nasal wall	
Lamella (named-anterior to posterior direction)	Anatomic correlate
First	Lateral extension of the uncinate process
Second	Lateral extension of the ethmoid bulla
Third	Middle turbinate attachment
Fourth	Superior turbinate attachment
Fifth	Supreme turbinate attachment (if present)

Table:1.3 Summary of four PNS (development, volume, arterial supply, venous supply and innervation) (Hwang & Abdolkhani, 2009; Standring, 2008)

Summary of four PNS (development, volume, arterial supply, venous supply, lymphatic drainage and innervation)						
Sinus	Intrauterine	Postnatal	Adult volume	Arterial	Venous, Lymphatic	Innervation
Maxillary	Develops as a bud from inferolateral surface of nasal capsule (day 65)	Present at birth, with two growth spurts between 1 to 4 years and 4 to 8 years	15ml	Branches of maxillary artery via superior anterior, middle and posterior alveolar arteries, infraorbital and greater palatine arteries	Veins follow the arteries and drain into facial vein or pterygoid venous plexus, Submandibular nodes	Infraorbital and anterior, middle, and posterior superior alveolar branches of maxillary nerve and nasal branches of pterygopalatine ganglion
Ethmoid	Develops as evagination of lateral nasal wall (3rd month)	Present at birth, with two growth spurts between 0 to 3 years and 7 to 12 years	14ml	Nasal branches of sphenopalatine artery, anterior and posterior ethmoidal branches of ophthalmic artery	Venous drainage is by corresponding veins, Submandibular and retropharyngeal nodes	Anterior and posterior ethmoidal nerves of ophthalmic nerves and orbital branches of pterygopalatine ganglion
Frontal	Upward extension of nasal capsule in frontal recess area (4th month)	Seen radiologically 7 to 12 years and adult size by age 20	6 to 7ml	Supraorbital and anterior ethmoidal arteries	Supraorbital and superior ophthalmic veins,	Branches of supraorbital nerve (ophthalmic nerve) and orbital branches of

					Submandibular nodes	pterygopalatine ganglion
Sphenoid	Evagination of posterior capsule in sphenoethmoid recess (3rd month)	Visible radiologically 3 to 4 years and further posterior extension begins by seventh year	7.5ml	Posterior ethmoidal branches of ophthalmic artery and nasal branches of sphenopalatine artery	Posterior ethmoidal veins draining into superior ophthalmic veins, Retropharyngeal nodes	Posterior ethmoidal branches of ophthalmic nerve & orbital branches of pterygopalatine ganglion

1.1.1.5 Maxillary sinuses

The maxillary sinus originates as an outpouching of the lateral nasal wall at the 10th week of intrauterine life. It starts superiorly and posterior to the ethmoturbinal (descending portion- developing uncinate process) and maxilloturbinal (developing inferior turbinate) respectively. As the resorption of nasal capsule occurs, it allows the maxillary sinus to occupy the space in developing maxillary process. At birth maxillary sinus is present but it continues to expand and grows in early childhood with the development and growth of maxilla and teeth. During childhood the floor of maxillary sinus gradually descends. The floor of maxillary sinus lies above that of the nasal cavity until the age of nine. As further growth occurs the floor is mostly at the level of the nasal floor and continues to descend as the maxillary sinus starts pneumatization at the age of nine. The pneumatization of the maxillary sinus brings the maxillary dentition into close proximity with maxillary sinus, so dental disease can cause maxillary sinusitis (Hwang & Abdolkhani, 2009).

1.1.1.6 Ethmoid sinuses

In 3rd month of intrauterine life, the ethmoid sinus develop as evaginations of the lateral nasal wall. The anterior ethmoid cells commence their development anterior to the second ethmoturbinal, while the posterior ethmoid cells begins to develop posterior to the second ethmoturbinal, therefore explaining why the basal lamella of the middle turbinate (second ethmoturbinal) eventually defines the functional drainage pathway of the both sinuses namely, anterior and posterior ethmoid sinsues. Anterior to the basal lamella of the middle turbinate the anterior ethmoid drains through middle meatus, whereas posterior to basal lamella the posterior ethmoid drains through the superior meatus. At birth ethmoid cells are present and pneumatize further between years 0 to 3 and 7 to 12 (Hwang & Abdolkhani, 2009).

1.1.1.7 Frontal Sinuses

During 4th fetal month, an outpouching originates medial to the most upper part of the uncinate process. This outpouching is called as frontal recess. After birth the frontal recess grows in cephalic direction to form the frontal sinus which becomes radiologically visible at years 7 to 12. The both frontal sinuses namely, right and left frontal sinus grow independently therefore accounting for their asymmetry (Hwang & Abdolkhani, 2009).

1.1.1.8 Sphenoid Sinuses

The unique sphenoid sinuses do not develop from outpouchings of the lateral nasal wall, but originate within the nasal capsule of the developing nose. Until the age of three, they remain undeveloped. At the age of 7 pneumatization of sphenoid sinus has typically reached the sella turcica and by the age of 9 to 12 pneumatization is generally complete. Sometime posterior pneumatization is arrested, it can give rise to three configurations of the sphenoid sinus: fetal (conchal), juvenile (presellar), and adult (sellar) as shown in Figure 1.3. The sellar type is the most common type of sphenoid sinus pneumatization representing 86% of adult sinuses, whereas juvenile (11%) and fetal (3%) variants are less common. It is good for surgical approaches to have well pneumatized sphenoid sinus since sensitive structures such as optic nerve, sella, and internal carotid artery are skeletonized and well vascularized. Hypo-pneumatized sphenoid sinus requires drilling of sphenoid bone to access skull base and making surgical approaches more difficult (Hwang & Abdolkhani, 2009).

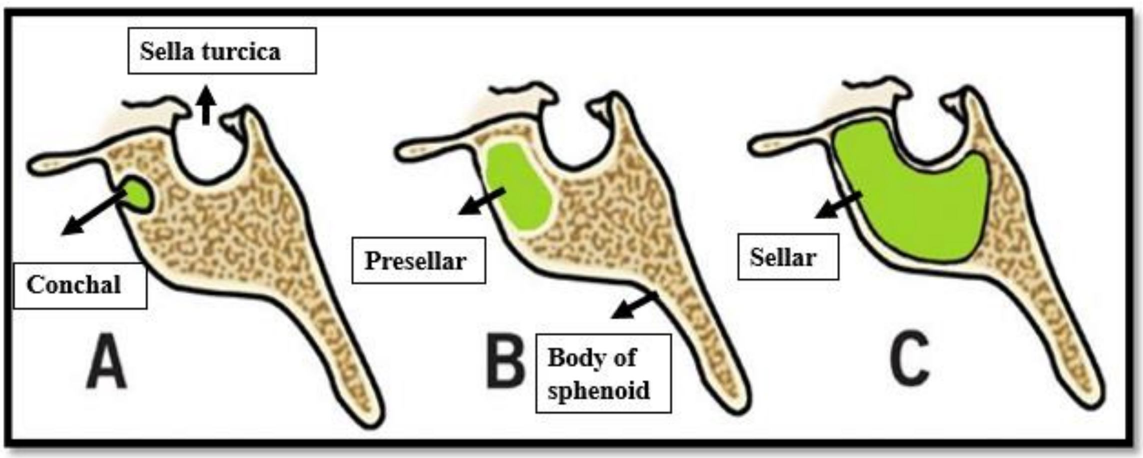


Figure 1.3 Variable configurations of sphenoid sinus based on degree of pneumatization. (A) conchal, (B) presellar, (C) sellar (Hwang & Abdolkhani, 2009)

1.1.2 Microscopic anatomy

The nasal cavity and PNS are lined by pseudostratified ciliated columnar epithelium, which consist of four cells namely, ciliated columnar epithelial, non-ciliated columnar, basal and goblet cells as shown in Figure 1.4. The ciliated respiratory epithelial cells are present all over the respiratory zone except for nasal vestibule, the posterior oropharyngeal wall, portions of the larynx, and terminal rami of respiratory bronchial tree. In each ciliated cell there are 50 to 200 cilia. The single cilium has a 9 plus 2 microtubular structure with dynein arms. The research shows typical ciliary beat frequency of 700 to 800 times a minute, with muco-ciliary passage occurring at a rate of 1cm/minute (normal range can vary widely). Non-ciliated cells possess microvilli which are present at apical aspect of each cell to increase surface area. The function of basal cell is unknown and goblet cells producing glycoproteins which are necessary for normal viscosity plus elasticity of mucus and are in strict control of parasympathetic and sympathetic neural inputs. Normal nasal mucosa of 160 cm^2 of nose secret 20 to 40 mL of mucus daily. In sol layer the cilia beat inside the lubricating periciliary layer fluid, and the more viscous mucus layer is outer gel layer. The outer gel layer offers a confluent lining for the nasal cavity on which inhaled particles can impact (Hwang & Abdolkhani, 2009).

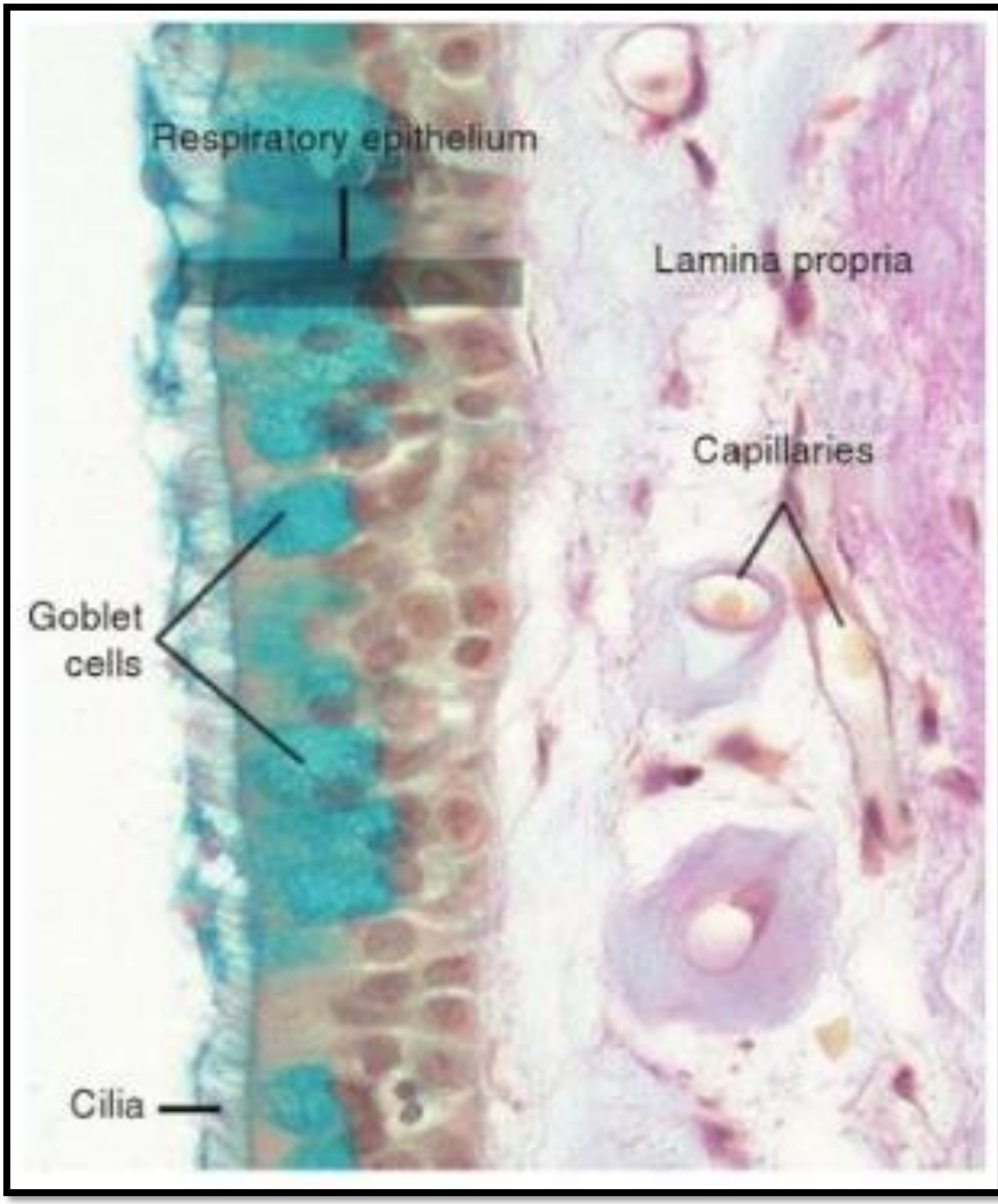


Figure 1.4 Tissue sample of inferior turbinate stained with Alcian blue and Van Gieson showing microscopic structure of respiratory epithelium (Hwang & Abdolkhani, 2009)

1.1.2.1 Muco-ciliary Clearance

The ciliated respiratory epithelium has cilia which move mucus in an organized and directional way through nasal cavity and PNS toward nasopharynx and pharynx from where the mucus is swallowed. The muco-ciliary clearance aids hygienic purpose to clear the nose of particulate debris and by any kind of infection or inflammation. Flow of mucus within can be mapped for each sinus, as shown in example of frontal and maxillary sinuses (Figure 1.5).

1.1.2.2 Osteo-meatal Complex (OMC)

The OMC is a common pathway of muco-ciliary clearance for anterior ethmoid, maxillary and frontal sinuses. The OMC complex is a functional area. It undergoes several structures that drain into middle meatus namely, maxillary ostium, ethmoid infundibulum, anterior ethmoid cells, and the frontal recess as shown in Figure 1.6. Inflammation or any mass obstruction in the OMC can disturb the muco-ciliary flow and thereby causing rhinosinusitis (Hwang & Abdolkhani, 2009). The anatomical variations disturbing OMC includes DNS (deviated nasal septum), CB (concha bullosa), bent middle turbinate, agger nasi cells, haller cells and many other variants. These OMC anatomical variants can cause meatal narrowing and even obstruction of sinus. Knowledge of the anatomical variations does reduce the surgical complication rates during Functional Endoscopic Sinus Surgery (FESS), and helps explain recurrence of disease. It also allows one to change the operative technique for the benefit of patient. CT PNS has vital role in presurgical evaluation of minimally invasive FESS (Jagannathan, Kathirvelu, & Hithaya, 2017).

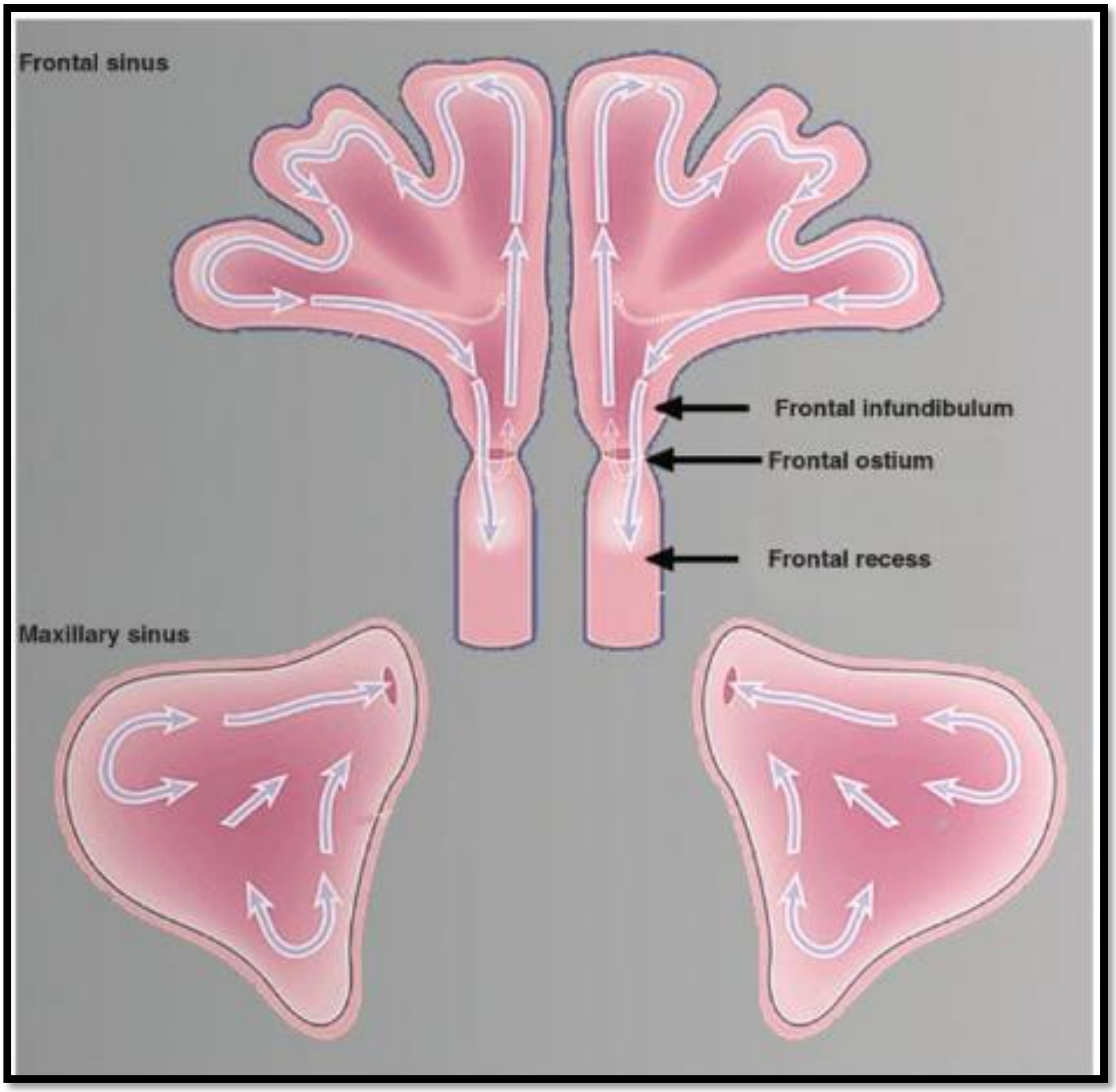


Figure 1.5 Mucociliary flow in frontal and maxillary sinuses (Hwang & Abdolkhani, 2009)

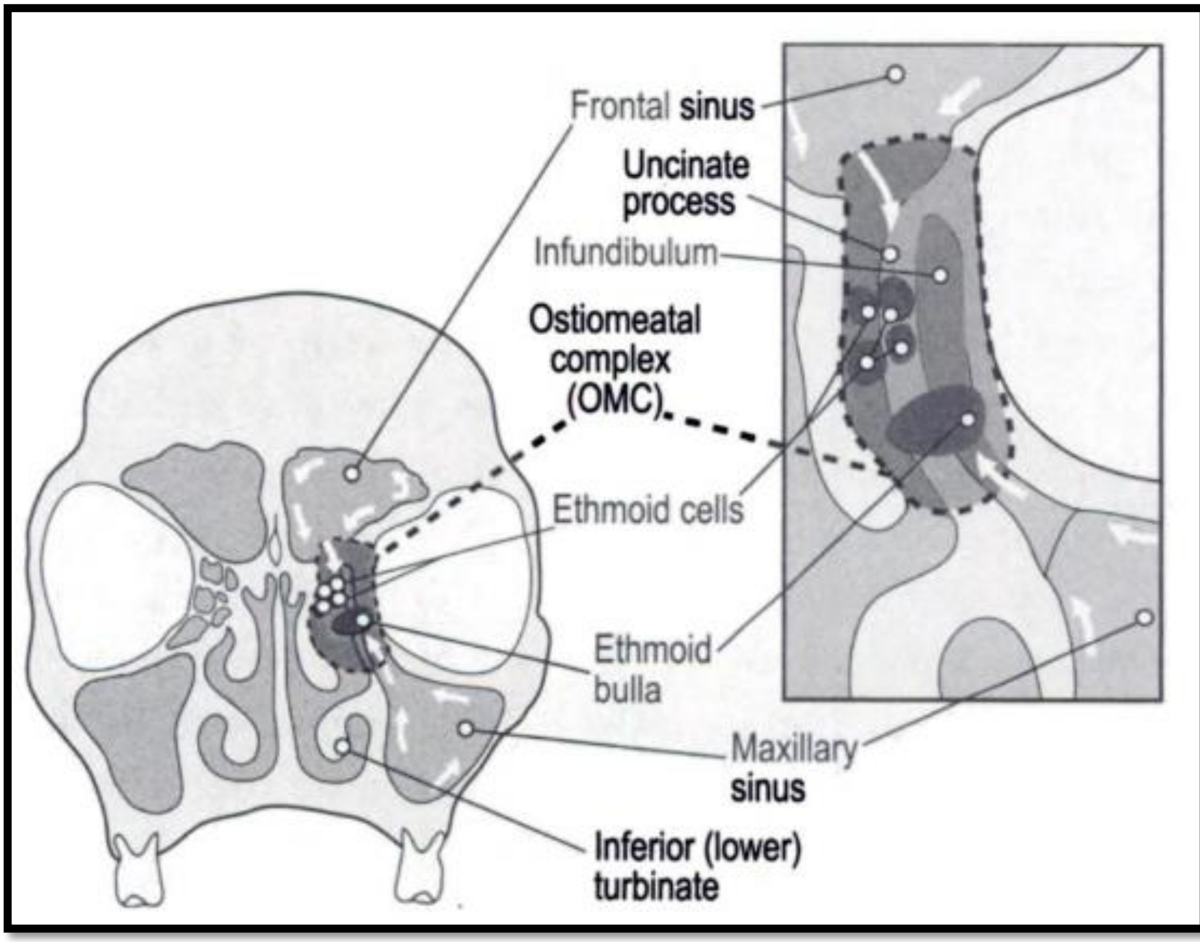


Figure 1.6 Osteomeatal complex (OMC) is called “the key to the sinuses” as frontal, maxillary and anterior ethmoid sinuses drain into this area (Josephson, 2006)

1.1.3 Gross Anatomy of the Sino-nasal region (Nose and PNS)

It is a part of respiratory tract which is located superior to the hard palate. The nose includes external nose and nasal cavity. The nasal cavity is divided into right and left nasal cavities by midline septum termed as nasal septum. In addition to olfaction, the nose helps in respiration, filtration plus humidification of the inspired air, reception and elimination of secretions from the PNS and nasolacrimal ducts. The boundaries of nasal cavity include, a roof, floor, medial and lateral walls. The roof of nasal cavity is curved and somewhat narrow, except at its posterior end, where the deep body of sphenoid forms the roof. The roof is further divided into three parts namely, frontonasal, ethmoidal, and sphenoidal named from the bones forming each part. The wider floor of nasal cavity is formed by palatine processes of the maxilla and horizontal plates of palatine bone. The medial wall is formed by midline nasal septum whereas, the lateral walls are irregular having three boney plates called nasal conchae, projecting inferiorly within the nasal cavity. The three nasal conchae, superior, middle and inferior, curve inferomedial as short curtain from the lateral wall of nasal cavity. The nasal cavity has five passages: a posterosuperior spheno-ethmoidal recess, three laterally located nasal meatus called superior, middle and inferior meatus, and a medially located common nasal meatus (part between conchae and nasal septum) into which all four lateral passages open. The superior meatus drains the posterior ethmoid air cells and the sphenoid sinus, the middle meatus receives the frontal sinus the maxillary sinus, and the anterior ethmoid air cells. The inferior meatus receives nasolacrimal duct (Moore, Dalley, Agur, 2014).

1.1.3.1 Gross Anatomy of Paranasal sinuses (PNS)

The PNS are 4 pairs of air-filled extensions of respiratory part of the nasal cavity within bones of skull namely, maxilla, frontal, ethmoid and sphenoid. The sinuses are named rendering to the bones in which they are situated. The nasal cavity and the PNS are important for various functions such as, decreasing the weight of the skull, warming and moisturizing the inhaled air, regulating speech resonance and intranasal pressure, and improve the sense of smell (Koo, Kim, Moon, Jung, & Lee, 2017).

Pathological changes within PNS are often of greater interest to radiologists than anatomical variations. But the anatomical variations of the nasal cavity and PNS are highly significant since they play a vital role in obstruction or drainage pathway of the OMC and sinus ventilation. Thus, anatomical variants of sino-nasal region elevate the risk of sinus mucosal diseases and various conditions. Furthermore, anatomical variations can affect the consequences and safety of surgical procedures performed in sino-nasal region such as FESS (Roman, Hedeşiu, Gersak, Fidan, Băciuţ, & Băciuţ, 2016).

1.1.3.2 Frontal sinuses

The pair of frontal sinuses is located between the two tables (outer and inner) of frontal bone, posterior to root of nose and superciliary arches. The pair of frontal sinuses namely right and left frontal sinus, drains via frontonasal duct into the ethmoidal infundibulum which opens into semilunar hiatus of the middle meatus (Moore et al., 2014).

1.1.3.3 Ethmoidal sinuses

Between the orbit and nasal cavity, the ethmoidal air cells are minor invaginations of nasal mucous membrane of middle and superior meatus into ethmoid bone. The anterior ethmoidal cells drain into middle meatus. The middle ethmoidal cells termed as bullar cells because bullar cells form ethmoidal bulla which is swelling on the superior border of the semilunar hiatus. The superior meatus receives opening of posterior ethmoidal cells. (Moore et al., 2014).

1.1.3.4 Sphenoidal sinuses

The pair of sphenoid sinuses are situated within the body of sphenoid and may extend into the wings of sphenoid bone also. The pair is divided unevenly by a bony septum called inter-sphenoid septum. The sphenoid sinus opens into superior meatus through sphenoethmoidal recess. The sphenoid sinus is surrounded by various important structures like internal carotid artery, cranial nerve II (CN-II, optic nerve), maxillary nerve and vidian nerve, any trauma to one of these vital neurovascular structures during surgery gives rise to harmful complications and increase the misery of the individual (Chougule, & Dixit, 2014).

1.1.3.5 Maxillary sinuses

The paired maxillary sinus is largest out of four pairs of paranasal sinuses. These are located in the bodies of the maxilla and have communication with middle meatus of the nasal cavity. This pair of sinus drains into middle meatus via semilunar hiatus (Moore et al., 2014).

1.1.4 Anatomical variations of nasal cavity and paranasal sinuses

1.1.4.1 Agger Nasi cells

The agger nasi cells are commonly found in majority of living population. Agger nasi cells are one of the most common anatomical variants of PNS, which is almost present in every individual. These cells are basically ethmoturbinal variant. These cells are stated as most anterior ethmoidal air cells that can extend into the lacrimal bone anteriorly. In relation to frontal recess these cells lie anterior, lateral and inferior to the frontal recess and also border frontal sinus and primary ostium. The better sight of frontal recess is attained by opening these anterior ethmoidal agger nasi cells. The size of agger nasi cells vary in every individual and may directly disturb patency of middle meatus and frontal recess (Reddy & Dev, 2012).

1.1.4.2 Frontal recess

The narrowest anterior air channel which communicate with frontal sinus is termed as frontal recess. It is one of the most common sites which is involved in infection and results in inflammation. The structures forming boundaries of recess include, the lamina papyracea laterally, middle turbinate medially and agger nasi cells forming the boundary anteriorly.

(Reddy & Dev, 2012). Research has reported that in 62% of subjects the frontal recess opens in middle meatus and in 38% individual opens into ethmoid infundibulum. (Kasper, 1936). The frontal recess is best appreciated on coronal imaging (CT-scan) superior to the agger nasi cells (Becker,1989).

1.1.4.3 Ethmoid infundibulum

The structures forming boundaries of the ethmoid infundibulum include, the uncinate process anteriorly, bulla ethmoidalis (anterior walls) posteriorly and the lateral boundary is formed by lamina papyracea. Through hiatus semilunaris, the ethmoid infundibulum opens into middle meatus. The structure bulla ethmoidalis is visible superior to the ethmoid infundibulum on coronal CT imaging. The floor of the ethmoid infundibulum receives opening of maxillary sinus ostium (Reddy & Dev, 2012).

1.1.4.4 Importance of the Ethmoidal roof

The roof of ethmoid sinus has got critical surgical importance mainly for two reasons, firstly ethmoid roof is most susceptible to iatrogenic cerebrospinal fluid (CSF) leaks. And secondly the important blood vessel namely, anterior ethmoid artery is exposed to trauma during surgical procedure, which could result in devasting bleeding within the orbit (Reddy & Dev, 2012). Mostly intracranial injuries occur during FESS, where the position of ethmoid roof is quite low (Dessi, Moulin, Triglia, Zanaret, & Cannoni, 1994).

By measuring the height of lateral lamella of cribriform plate which is part of ethmoid bone, the depth of olfactory fossa is determined. In 1962, Kero established a criterion which is surgically important called Keros classification for the depth of olfactory fossa which is of three types: type-1 (<3 mm), type-2 (4-7mm) and type-3 (8-16mm), illustrated in Figure- 1.7 (Jagannathan, Kathirvelu, & Hithaya, 2017). The most vulnerable to iatrogenic injury during surgical procedure is Kero type III (Kainz & Stammberger, 1988; Ohnishi, Tachibana, Kaneko, & Esaki, 1993; Stammberger & Hawke, 1993).

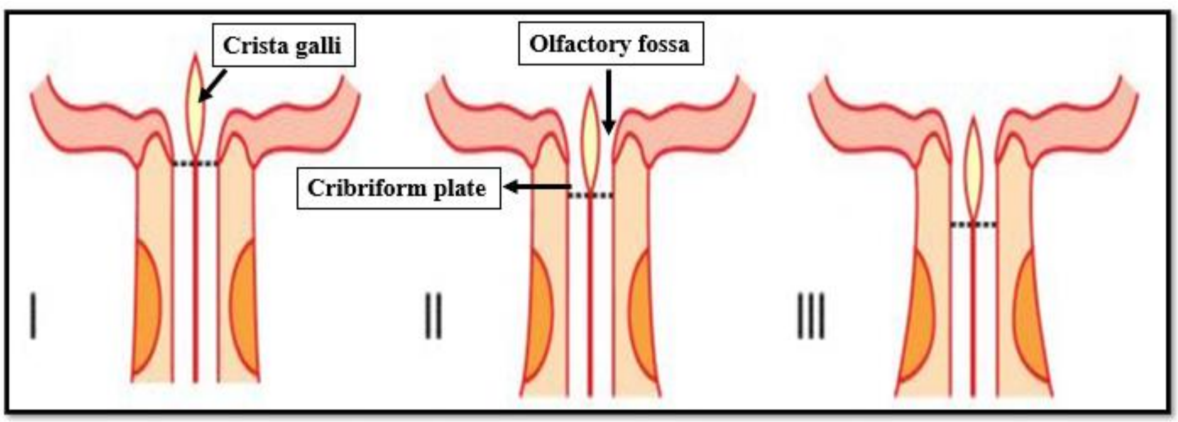


Figure 1.7 Keros 3 subtypes characterize varying depths of olfactory fossa measured by length of lateral lamella of cribriform plate. I) type 1, (1 to 3mm), II) type-2, (4 to 7 mm), III) type-3 (8 to 16 mm) (Hwang & Abdolkhani, 2009)

1.1.4.5 Onodi cells (sphenoethmoid)

The onodi or sphenoethmoid cells are basically posterior ethmoidal cells. The onodi cells extend into the sphenoid bone moreover adjacent to or invading the cranial nerve II (Stammberger & Kennedy, 1995). These posterior ethmoidal air cells adjoin or surround the CN-II. Thus, CN-II is at risk when surgical removal of onodi cells is done and it is a possible reason of incomplete sphenoidectomy (Reddy & Dev, 2012).

1.1.4.6 Significant Features of the Sphenoid Sinus

The pair of sphenoid sinuses possess a septum which is called inter-sphenoid septum. When this septum is bent towards one side, adjoining the thin bony wall casing the internal carotid artery, consequently, arterial damage could result if inter-sphenoid septum is avulsed while performing surgical procedure. In 65-72% of subjects the internal carotid artery may bulge within the sinus cavity. And in 4-8% of subjects there might be dehiscence/absence of the thin bony part separating the internal carotid artery and sphenoid sinus cavity (Laine & Smoker, 1992). Agenesis of the sphenoid sinus can also occur. Sometimes pterygoid canal or furrow of maxillary nerve (V2) may bulge into sinus, that may cause trigeminal neuralgia followed by sinusitis. Also, there could be pneumatization of the anterior clinoid process, which is frequently related with optic nerve, type II and type III, CN-II configuration, it can predispose optic nerve to injury during FESS (Reddy & Dev, 2012). Complications during surgery are because of extensive variation in anatomy of sphenoidal sinus such as level of pneumatization, inter-sinus septa, accessory septae, onodi cells and dehiscence of vital neuro-vascular structures within the sinus cavity (Chougule & Dixit, 2014).

1.1.4.7 Various configurations of the optic Nerve CN-II

In addition to vidian nerve and internal carotid artery, the second cranial nerve (optic nerve) also develops former to the PNS and are reason for numerous anatomical variations in the sphenoid sinus cavity and its walls. In 1996, Delano, Fun & Zinreich, characterized several relationships among optic nerve and posterior PNS which are of four types, Type-I: CN-II courses proximately adjacent to sphenoid sinus, without indentation of the sinus wall or contacting with the posterior ethmoid air cell and type-I is the most common type, Type-II: CN-II courses adjacent to the sinus cavity, producing an indentation of the sinus wall, but do not contact with posterior ethmoid air cell, Type-III: CN-II progresses through the sphenoid sinus cavity surrounded with air approximately 50% of the nerve, Type-IV: CN-II courses proximately adjacent to two sinuses namely, sphenoid and posterior ethmoid sinus. Delano et al., revealed that in 85% of the subjects the optic nerve was related with pneumatized anterior clinoid process mostly type II and type III configurations of optic nerve was observed. And out of these 85% of the subjects, 77% exhibited dehiscence, signifying the susceptibility of optic nerve during FESS. The inter-sphenoid septa might be closely attached to the bony canal of the CN-II, influencing it to trauma during surgical procedures (Delano et al., 1996).

1.1.4.8 Deviated Nasal septum (DNS) and Common Nasal Turbinate Variations

The midline nasal septum divides the nasal cavity into right and left halves. When the position of midline nasal septum is altered or deviated, it is called as deviated nasal septum (DNS). Altered nasal septum occludes most of the nasal cavity considered as DNS. DNS may result in compression of turbinate causing blockage of sinus drainage pathway and increases chances of infection and inflammation of the sinuses (Kumar & Prasad, 2016). Ozcan, Selcuk, Özcan, Akdogan, & Dere, (2008) has reported that after the widespread use of FESS and CT-PNS, several anatomical variations of nasal turbinates have been identified and explained. The anatomical variations of nasal turbinate include pneumatization of turbinates namely, superior, inferior and middle turbinate, out of these middle one is common for anatomical variations of nasal cavity. Also, there could be bifid inferior turbinate including secondary and accessory middle turbinate which are rare nasal turbinate variants. While examining the patient endoscopically these anatomical variations can be overlooked but can be easily identified by computed tomography of PNS.

1.1.4.9 Paradoxical curvature of middle turbinate (MT)

The convexity of the middle turbinate is directed medially toward the midline nasal septum normally, but if the convexity of middle turbinate is directed laterally, it is called as paradoxical curvature of middle turbinate. Research shows that the paradoxical curvature of nasal turbinate could be a causative reason for various sinus mucosal infections such as sinusitis (Ozcan et al., 2008; Reddy & Dev, 2012).

1.1.4.10 Concha Bullosa (CB)

The CB denotes occurrence of air cells within the turbinates called pneumatization of nasal turbinate. The middle turbinate (MT) is most commonly involved as pneumatization occurs because of variation in the development of ethmoidal air cells. The CB is usually asymptomatic and diagnosed incidentally by CT-PNS. If MT is over-pneumatized it can result in nasal obstruction, facial pain, headache, DNS, sinus infection namely, acute sinusitis leading to chronic sinusitis. Any infection or disease of PNS can disturb the CB, resulting in thickening of mucosal lining, accumulation of mucous, mucocele and pyocele within the pneumatized nasal turbinate. The CB can be a reason for mechanical obstruction of various sinuses, also affecting sinus drainage pathway resulting into sinusitis (Kalaiarasi et al., 2018). The reported incidence rates for pneumatized MT is between 13 and 53.6% (Al-Sebeih & Bu-Abbas, 2014; Joe, Ho, & Yanagisawa, 2000; Lee, Hong, Roh, & Cho, 2013; Unlü, Akyar, Caylan, & Nalca, 1994). CB also called as MT pneumatization, it is a normal anatomical variant and is one of the most common and obstructive variants of sinonasal region observed in cases of sinusitis. CB is an aerated turbinate; mostly middle one is involved. CB of middle turbinate is of three types, which are: Lamellar CB: If pneumatization of the attachment portion of MT occurs it is termed as lamellar CB (vertical lamella MT pneumatization). Bulbous CB: If pneumatization of the bulbous segment occurs it is termed as bulbous CB (inferior portion MT pneumatization). Total CB (Extensive): If pneumatization of both parts occurs namely, lamellar and bulbous then it is called total or extensive CB (vertical plus inferior portion MT pneumatization) (Ozcan et al., 2008; Reddy & Dev, 2012; Stallman, Lobo, & Som, 2004). Reddy & Dev, (2012) reported that, CB can obstruct ethmoid infundibulum.

1.1.4.11 Variations of the Uncinate Process (UP)

The uncinate process is derived from a Latin word, "processus uncinatus", which means "hooked outgrowth". It is the leftover of the descending portion of the first ethmoturbinal ridge. It resembles a thin bony leaflet that looks like a hook (Stammberger & Kennedy, 1995). On coronal computed tomography, posterior sections reveal UP as a tiny thin bone which is connected inferiorly to the inferior turbinate, with a free edge posteriorly. And anterior sections reveal that the UP is closely attached superiorly to the base of skull, medially to middle nasal turbinate, and attached laterally to the lamina papyracea or ethmoidal agger nasi cells (Figure- 1.8). There are various anatomical variations of UP which include, medialized, lateralized, pneumatized or bent UP whereas the medialized UP is mostly observed with giant bulla ethmoidalis. The lateralized UP may cause obstruction of ethmoid infundibulum. Its pneumatization is called as uncinate bulla which is rare, and may be seen in 4% of the population, causing obstruction of the infundibulum (Bolger, Parsons, & Butzin, 1991).

1.1.4.12 Haller cells/Infraorbital cells

In 1765, a swiss anatomist, Albrecht von Haller, first described Haller's cells. These cells are also termed as maxilloethmoidal or orbitoethmoidal cells (Raina, Guledgud, & Patil, 2012). These cells are basically extensions of ethmoid cells that can be visualized in numerous imaging modalities. Research has shown that idiopathic orofacial pain is associated with the presence of Haller cells. Haller cells are in close relation with various structures which includes, as these cells project along the medial side of roof of maxillary sinus cavity, inferior part of the lamina papyracea, beneath the ethmoid bulla, and are in lateral relation to the uncinate process. These cells can cause narrowing of the infundibulum, along with this, haller cells may compromise maxillary sinus ostium therefore responsible for recurrent maxillary sinusitis (Kumar, Sudarshan, Vijayabala, Srinivasan, & Kini, 2018).

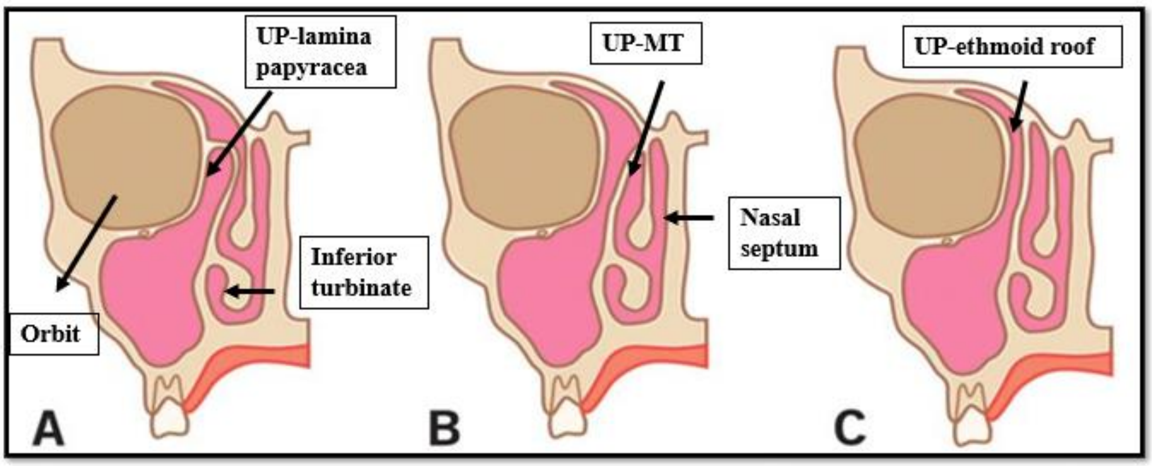


Figure 1.8 Variable attachment of Uncinate Process (UP) can either to be: (A) the lamina papyracea; (B) the middle turbinate (MT); or (C) the ethmoid roof (Hwang & Abdolkhani, 2009)

1.1.4.13 Bulla Ethmoidalis

The bulla ethmoidalis is derived from Latin word, bulla ethmoidalis. The term bulla means a hollow, or thin bony prominence. Bulla ethmoidalis is formed when there is pneumatization of the bulla lamella or second ethmoid basal lamella occurs. It looks like a bleb on lamina papyracea (Stammberger & Kennedy, 1995). The bulla ethmoidalis is the most prominent and largest nonvariant air cell in anterior ethmoid complex that is related to lamina papyracea laterally. This structure may fuse with base of skull superiorly and with lamella basalis posteriorly. On the coronal computed tomographic imaging bulla ethmoidalis is observed superior to the infundibulum. As the pneumatization degree varies, failure to pneumatize is termed torus ethmoidalis. The 'giant bulla' may cover entire middle nasal meatus and force its way among the uncinate process and the middle turbinate (Dwivedi & Singh, 2010).

1.1.4.14 Posterior Nasal Septal Air Cell

In midline nasal septum the pneumatized posterior nasal septal air cells can be visualized in the posterosuperior portion. The posterior nasal septal air cells can communicate with sphenoid sinus cavity. Various sinus mucosal diseases occur within PNS, that may disturb posterior nasal septal air cells. It can resemble a cephalocele. Computed tomography is useful to differentiate this entity and posterior nasal septal air cells (Shokri, Faradmal, & Hekmat, 2019).

1.1.4.15 Aerated Crista Galli

It lies on the midline of the cribriform plate. Embryologically, the crista galli is derived from the ethmoid bone. The crista galli is generally bony structure. Once this crista galli is aerated, then it can interconnect with frontal recess, obstructing sinus ostium and therefore leading to sinus mucosal diseases such as sinusitis. Aerated crista galli has got crucial importance in order to identify and differentiate this structure from an ethmoid air cell, before planning any endoscopic surgery to prevent unintended access into the anterior cranial fossa (Socher, Santos, Correa, & Silva, 2013).

1.1.5 Rhinosinusitis

The condition rhinosinusitis is defined as symptomatic inflammation of mucosa of nasal cavity and PNS, and if it lasts for less than four weeks then, it is called as acute, or if it lasts for more than four weeks then it's termed as chronic rhinosinusitis. It is the fifth most common reason for an antibiotic prescription and prevalent among all age groups. Moreover, according to recent guidelines for antibiotic resistance and the cautious use of antibiotics, it is indispensable to have clear treatment procedures available for such a common diagnosis (Aring & Chan, 2016; DeBoer & Kwon, 2019). Sinusitis is the second most common infectious disease observed by physicians (Worrall, 2011). The word "rhinosinusitis" is preferred to "sinusitis" since inflammation or any sinus mucosal infection of the sinuses rarely happens without concurrent inflammation of the nasal mucus membrane. Sinusitis can be caused by various allergens, irritants, microbes like viruses, fungi, and bacteria. Common irritants include, animal dander, polluted air, smoke, and dust particles. The sinusitis can cause mechanical obstruction and impaired mucociliary drainage pathway of the sinuses. The detailed knowledge and better understanding of the complex variable anatomy of the PNS is vital for clinicians and surgeons. Computed tomography of PNS provide a precise assessment of various normal anatomical variants including sinus mucosal changes essential for successful FESS (Battisti & Pangia, 2019). The higher rates of affected subjects with sinusitis are noticed in the South, Midwest, and mostly among women. The most commonly affected ones are adults age ranges from 25 to 64 years of age (Lemiengre, et al., 2018).

The rationale of this study is to highlight the importance of anatomical variations of nasal cavity and paranasal sinuses on computed tomography in order to emphasize on their surgical significance before planning for surgical procedure such as FESS. In addition to surgical significance this study will also help to asses association between gender, symptoms of sinusitis and anatomical variants of sinonasal region as detected on CT-scan imaging.

1.2 Hypothesis

A) Null Hypothesis

There is no association between anatomical variants of sinonasal region and symptoms of sinusitis as detected on CT-scan.

B) Alternate Hypothesis

There is association between anatomical variants of sinonasal region and symptoms of sinusitis as detected on CT-scan.

1.3 Objectives of Study

A) To determine the incidence of sinonasal anatomic variants in symptomatic subjects of sinusitis on CT-scan.

B) To assess association between anatomic variants of sinonasal region and symptoms of sinusitis on CT-scan.

C) To assess association between gender and symptoms along with anatomical variations of sinonasal region on CT-scan.

1.4 Problem Statement

Sinusitis complicates almost 0.5% of upper respiratory tract infections. The reported incidence of sinusitis ranges from 15 to 40 episodes per 1000 patients annually. It is more prevalent in adults affects nearly 1 in 7 adults, as in children sinuses are not completely developed. Sinusitis is the second most common infectious disease observed by physicians (Worrall, 2011). Hence it is the fifth most common reason for an antibiotic prescription and resulting in antibiotic resistance (Aring & Chan, 2016; DeBoer & Kwon, 2019). Some organs of human body are subject to remarkable anatomical variations and changes relation with nearby vital structures, the sinonasal region is one of them. The anatomical variants disturb the mucociliary sinus drainage pathway hence causing sinusitis (Tiwari & Goyal, 2015). Although FESS is choice of treatment but not without risks as the anatomy is highly complex (Krings et al., 2014). The incidence of FESS complications ranges from 0.4% to 30%. The variable anatomy and proximity of sinuses to vital structures such as orbit, brain exposes it to the risk of injury and some of those complications could be serious, and leading to permanent dysfunction (Seredyka-Burduk, Burduk, Wierzchowska, Kaluzny & Malukiewicz, 2017).

Literature has proved that while performing any kind of surgical technique, surgeon must have idea of anatomical variations of that particular structure. Research shows that anatomical variants of nasal cavity and paranasal sinuses are responsible for sinus mucosal infection. Anatomical variations which are normal and can be present in every individual should not be ignored while planning for surgical procedure. Intraoperative complications of FESS can be orbital hematoma, CSF (cerebrospinal fluid) leak, ocular trauma, damage to optic nerve (CN-II), blindness, carotid-cavernous fistula hemorrhage, intracranial injury, cellulitis, subcutaneous orbital emphysema, epiphora, synechiae and many other which can increase not just the misery of the individual but also increase the burden of disease in the community.

Keeping in mind this issue, with the help of CT-PNS surgeons can identify anatomical variations and by avoiding these hazards of FESS can provide better quality of life to individual after going through any surgical technique.

1.5 Significance of Study

It is still debatable that whether anatomical variations of nasal cavity and paranasal sinuses are causative factor for sinusitis. In addition, whether association exists between anatomical variants of sinonsal region such as deviated nasal septum (DNS), onodi cells including many other variants and symptoms of sinusitis for instance nasal obstruction, headache, facial pain and rhinorrhea. Enhancement in functional endoscopic sinus surgery (FESS) and computed tomography (CT) have concomitantly amplified interest in variation of the nasal cavity and paranasal sinus region anatomy.

CT scanning is painless, special x-ray equipment is used to evaluate and assess the paranasal sinus cavities. CT scan must be performed before planning for FESS surgery, in order to identify sinus drainage pathway and anatomical variants. By using CT-PNS surgeon can avoid known hazards of FESS such as blindness, ocular dysfunction, orbital hematoma, CSF leak, carotid-cavernous fistula and many other deadly complications.

This prospective study will help to determine the incidence of anatomical variants in symptomatic subjects of sinusitis and assess association between gender, symptoms of sinusitis and anatomical variations of sinonasal region as detected on CT-scan.

1.6 Operational Definitions

1.6.1 CT Scan

Computed tomography (CT) is a type of structural imaging technique in which X-rays are used to create tomography that is cross sectional images. The procedure of this technique involves patient lying onto a scanner table and then passes through the CT gantry, in which X-ray tube is present and an oppositely located array of X-ray detectors are present which rotate about the patient. Large number of X-ray projections are attained from multiple angles at each slice position in the patient, each of which contains data regarding the differential attenuation of x-rays by different tissue types in the patient. These projections are then used by a computer to reconstruct CT images (Torigian & Ramchandani, 2017).

1.6.2 Sinusitis

The inflammation of sinus mucosa is called as sinusitis. It includes acute and chronic sinusitis which depends upon the duration of involvement of sinus. Acute inflammation of sinus mucosa is that which lasts for less than six weeks is called acute sinusitis. Sinus infection lasting for more than six weeks or months or years is called chronic sinusitis. The sinus most commonly involved is the maxillary followed in turn by ethmoid, frontal and sphenoid. Very often, more than one sinus is infected (multisinusitis). Sometimes, all the sinuses of one or both sides are involved simultaneously (pansinusitis unilateral or bilateral). Sinusitis may be open or closed type depending on whether the inflammatory products of sinus cavity can drain freely into the nasal cavity through the natural ostia or not. A closed sinusitis causes more severe symptoms and is also likely to cause complications (Dhingra, 2014).

1.6.3 Nasal Obstruction

Nasal congestion is the obstruction or blockage of the nasal passage and this is the most common symptom of nasal and paranasal sinuses (PNS) pathologies. Nasal obstruction may be intermittent or constant, unilateral or bilateral, congenital or acquired and acute or chronic in nature **(**Udaipurwala 2013).

1.6.4 Headache & Facial pain

Headache and facial pain may occur due to any kind of pathology involving nose and paranasal sinuses. Due to the involvement of sinuses pain occurs in head and sinus region. Sinusitis is one of the important causes of headache and facial pain (Udaipurwala 2013).

1.6.5 Rhinorrhea

Rhinorrhea is defined as discharge from the nose. It may be watery, mucoid, mucopurulent or blood stained in nature. Nasal discharge may be unilateral or bilateral (Udaipurwala 2013).

CHAPTER 2

LITERATURE REVIEW

There are 4 paired paranasal sinuses (PNS) in every individual. Histologically these sinuses are lined with pseudostratified columnar epithelium. The four-air filled sinuses include, maxillary sinus which is largest of the all, located underneath the eyes within the maxillary bones, the frontal sinus which is located superior to the eyes within the frontal bone, the ethmoid sinus is formed from numerous distinct air cells inside the ethmoid bone between the eyes and nose, while the sphenoid sinus is located within the body of sphenoid bone. The functions of these sinuses are various as they are implicated in several roles, decreasing the relative weight of the skull, improving the resonance of the voice, acting as a buffer against facial trauma, insulating delicate structures from rapid temperature fluctuations in the nose, humidifying and heating inhaled air, and immunological defense against various microbes (Al-Abri et al., 2014; Fahrioglu & Andaloro, 2018; Gibelli et al., 2017; Roman et al., 2016; Simmen & Jones, 2014; Smith et al., 2010).

Embryologically during eighth week of gestation the development of paranasal sinuses is indicated by appearance of series of folds and ridges on lateral nasal wall which are termed as ethmoturbinals. Initially six to seven folds emerge but only three to four ridges persist through the process of regression and fusion. The first ridge is rudimentary and it is incomplete in humans. The ascending portion forms agger nasi cells whereas descending portion forms uncinate process. The second ethmoturbinal ridge forms the middle nasal turbinate. The third ethmoturbinal ridge forms superior turbinate whereas fourth ridge along with fifth ridge fuses and forms supreme turbinate. With further progression of the development, furrows are formed between the ethmoturbinal ridges which forms rudimentary meati and recesses (Cappello & Dublin, 2018).

Out of four paired air-filled sinuses the maxillary sinus is largest of all and it is pyramidal in shape whose apex lies in zygomatic process of maxilla whereas base is formed by the lateral wall of nose. The two fossae namely infratemporal and pterygopalatine lie behind the posterior wall of the sinus. The floor of orbit forms the roof of the sinus whereas the floor is formed by alveolar part of maxilla. As the adult size of sinus varies, some are large so that they extend into zygomatic process or alveolar process of maxilla and that is why roots of premolar and molar teeth lie below the floor of sinus or project into the maxillary sinus. This pyramidal sinus drains through its ostium that opens at posterior part of infundibulum, and finally empties into middle meatus. Sometimes accessory ostium is present which opens anteriorly or posteriorly into the lower part of uncinate process of inferior turbinate of the lateral nasal wall (Kantún, Acosta & María, 2019; Onwuchekwa & Alazigha 2017).

The ethmoid sinus lies within the ethmoid bone. The delicate ethmoid bone is consisting of four parts which includes, cribriform plate which is horizontal lamina, a perpendicular plate, and two lateral masses which are called labyrinths. The lamina papyracea is formed by lateral wall of labyrinth which forms the medial wall of the orbit. The ethmoidal labyrinth possesses various thin walled variable air cells that are arranged in three groups which are anterior, middle and posterior groups. The anterior ethmoid along with middle ethmoid drains through the infundibulum into middle nasal meatus whereas the posterior ethmoidal air cells open into superior nasal meatus (Kantún, Acosta & María, 2019; Onwuchekwa & Alazigha 2017).

The paired sphenoid sinuses occupy the sphenoid bone. There is thin bony septum which is present within the sinus and mostly posterior part of the sphenoid sinus is septate. It is known that this sinus is the most variable space of the human body and that makes it difficult to approach the sinus cavity. The size of sphenoid sinus depends on the degree of pneumatization. The sphenoid sinus is surrounded by vital neurovascular structures such as internal carotid artery, vidian nerve and second cranial nerve. The ostium of sphenoid sinus lies in anterior wall which is better demonstrated in axial computed tomographic images. Each ostium of the sinus opens into a recess known as sphenoethmoidal behind the upper concha which is common drainage for two sinuses the sphenoid sinus and posterior ethmoid cells (Kantún, Acosta & María, 2019; Onwuchekwa & Alazigha 2017).

The frontal sinus lies within the diploe space between the two tables of frontal bone that are outer table and inner table. Mostly both sinuses are unequal in size and extent. The paired frontal sinus is separated by a midline bony septum. Sometimes one frontal sinus is small or absent. The frontal sinus drains through frontal recess. The frontal recess is hourglass in shape, usually drains into middle nasal meatus in 62% of the subjects or into ethmoid infundibulum in 38% of the subjects (Kantún, Acosta & María, 2019; Onwuchekwa & Alazigha 2017).

For strong understanding of PNS anatomy and anatomical variations, it is important to understand the various anatomical relationships of the PNS to the surrounding structures. The lateral wall of nasal cavity contains several structures and recesses that are significant for understanding PNS anatomy such as, nasal turbinates which are three to four bony shelves that serve to increase the interior surface area, the three nasal meatuses which are spaces located below each turbinate. The superior meatus provides drainage for the sphenoid and posterior ethmoid sinuses. The middle meatus provides drainage for the frontal, anterior ethmoid, and maxillary sinuses. The inferior meatus receives orifice of the nasolacrimal duct. The uncinate process is a sickle-shaped, thin, bony part of the ethmoid bone, covered by mucoperiosteum, medial to the ethmoid infundibulum and lateral to the middle turbinate. The ethmoid infundibulum is a pyramidal space facilitating drainage of the maxillary, anterior ethmoid, and frontal sinuses. The semilunar hiatus is a gap that empties the ethmoid infundibulum and is located between the uncinate process and the ethmoid bulla. The osteomeatal complex (OMC) is a region referring to the anterior ethmoids containing the ostia of the maxillary, frontal, and ethmoid sinuses. This is located lateral to the middle turbinate. While not a discrete anatomic structure, it is instead a collection of several middle meatus structures including the middle meatus, uncinate process, ethmoid infundibulum, anterior ethmoid cells, and ostia of the anterior ethmoid, maxillary, and frontal sinuses (Cappello & Dublin, 2018).

Anatomical variations of sinonasal area were very common, and many authors classified these variants into four familiar groups: nasal septum variations for instance deviated nasal septum (DNS), middle turbinate variations like concha bullosa (CB), uncinate process variations, and ethmoidal variations. DNS was most common anatomical variant found in patients (48.8%) with acute/chronic or recurrent sinusitis. Agger nasi cells and CB were almost equally frequent (30.6%), and Haller cells were noticed in 11.2%. Uncinate process variants were noticed in 18.1%, and the large ethmoid bulla was seen in 10%. The significance of anatomic variations is that these variations can compromise sinus drainage pathway of the associated sinus, that could result in inflammatory sinus disease such as sinusitis. Overall anatomical variations are not diseases on their own and may exist as incidental findings in subject with sinusitis (Alsowey, Abdulmonaem, Elsammak & Fouad, 2017).

The mucosa lining of the PNS is prone to infection and inflammation. In 5th century B.C Hippocrates specified that, "In a person having a painful spot in head, with intense headaches, pus or fluid running from the nose removes the disease" which may be referred as sinusitis. Sinusitis is the inflammation or swelling of mucosal lining of paranasal sinuses (PNS), and the spaces that secrete mucus which is necessary for the nasal passages to work effectively. The sinusitis is one of the most common illnesses of the nose and PNS. Sinusitis affects 1 in 7 adults resulting in about 50 million individuals diagnosed with sinusitis every year around the globe (Rajashree, Deepthi & Viswanatha, 2018; Shoib & Viswanatha 2016; Sriprakash, 2017). This disease is increasing in epidemic proportions all over the world. Chronic and recurrent sinusitis have been recognized to influence negatively health-related quality of life (Alkire & Bhattacharyya, 2010).

Sinusitis occurs when there is impaired mucociliary apparatus function with meatal narrowing or even obstruction, excessive mucus production or excessive mucus builds up, stagnant mucous collection and the sinuses become inflamed. Sinusitis can be acute or chronic, it can occur due to various reasons, such as viral, bacterial, fungal infection, allergic reactions, or even it can occur due autoimmune reactions (Dhingra, 2014).

In last few years, functional endoscopic sinus surgery (FESS) has become a gold standard in the treatment of chronic or recurrent rhinosinusitis. Therapeutic outcomes depend on preoperative evaluation of the patients. Computed tomography (CT) of the paranasal sinuses (PNS) displays good sensitivity and specificity for the early diagnosis of rhinosinusitis and detection of anatomical variations of sinonasal region. Combination of medical history, physical examination, and in addition to it CT may increase accurateness of diagnosing the various sinus pathologies for instance rhinosinusitis (Al-Abri et al., 2014; Khojastepour, Mirhadi, & Mesbahi, 2015; Maru, Rusu, & Sandulescu, 2015).

With the invention of FESS and CT, significant attention has been directed towards the anatomy of the PNS region. Detailed knowledge of anatomical variations in the PNS area is of critical value for surgeons executing endoscopic sinus surgery as well as for radiologists that are involved in the preoperative work-up of the patients (Bhargava, Bhargava, Al-Abri, Al-Bassam & Al-Abri, 2011).

Anatomical variations are normal and can be present in every individual. The importance of anatomical variants can’t be ignored as presence of various anatomical variants produce diversity of relationships to a structure in which they lie. The sinonasal cavities possess multitude of anatomic variants, out of which some are so common that they are most likely present in the majority of the population. In 2015 it was revealed that no significant difference in the prevalence of any of the PNS or nasal cavity anatomical variants between patients with minimal and patients with clinically significant radiologic evidence of sinus mucosal disease. But analysis of every routine CT-PNS obtained for rhinosinusitis for the presence of diverse anatomic variants is of questionable value unless surgery is planned. For cases who are planning to undergo FESS or other skull base surgery, however, it is important to be aware of certain anatomic variants, such as onodi cells, supraorbital cells, infraorbital haller cells, and many others. Failure to recognize these anatomic variants is associated with a higher rate of surgical complications (Loftus, Lin & Tabaee, 2016; Shpilberg, Daniel, Doshi, Lawson & Som, 2015).

The diseases of the nasal cavity and PNS are among the most common pathologies which bump into the clinics of the ear, nose, and throat (ENT). Anatomic variations of sinonasal region are also frequently observed, and they play a vital role in dysfunctional drainage of sinus cavities, generally resulting in acute sinusitis followed by chronic sinusitis. In 2017 a study revealed rate of sinusitis was observed in study group 82.3% (Devaraja, Doreswamy, Pujary, Ramaswamy & Pillai, 2019; Güngör & Okur, 2019; Kaya, Çankal, Gumusok, Apaydin, & Tekdemir, 2017). Overall, the anatomic variations of nasal cavity and PNS were identified in 325 out of 350 patients (92.9%). And the most common anatomical variation was deviated nasal septum (DNS) (89.7%) followed by agger nasi cells (72%) and concha bullosa (CB) (51%) (Kaya et al., 2017).

PNS are a group of pneumatized spaces developed as an extension of the nasal cavities, eroding the adjacent bony structures. According to the research, some regions present a high risk for trauma and significant intraoperative complications, with the frontal and ethmoid sinuses being most frequently affected. Anatomical variations, in correlation with their inherent conditions, are added to surgical risks so the knowledge of these vital structures is critical for endoscopic surgeons as well as for radiologists contributing in the preoperative evaluation of the patients, in order to avoid therapeutic letdown and complications. The gaining of an excellent definition of the sinonasal anatomy for a preoperative evaluation can be done by computed tomography that is the gold standard in the study of complicated structures, for providing accurate information on soft tissues, bony regions and presence of air cells, thus characterizing a highly sensitive method of imaging (de Miranda et al., 2011).

The incidence of different anatomic variations was evaluated radiologically in the southern region of Saudi Arabia to specify racial or age groups differences and emphasized on their clinical importance. The DNS was observed in 30.7%, CB was present in 24.2%, superior turbinate pneumatization in 1.7%. Paradoxical middle turbinate in 9.5%, crista galli pneumatization in 8.7%, uncinate process attachment to lamina papyracea in 73.7%, frontal sinus was hyper-pneumatized in 26.3%, frontal air-cell in 25.9%, supraorbital air-cell in 37.5%, Onodi cell in 31.4%, Haller cell in 25.9%, hyper-pneumatization of sphenoid sinus was observed in 24.2%, anterior ethmoid artery running within the sinus cavity in 29.4%, posterior ethmoid artery running within the sinus cavity in 5.5%, type II depth of cribriform plate in 45.4%, internal carotid artery dehiscence in 20.8%, optic nerve was dehiscence in 15%, intersphenoid septum was attached to the carotid canal in 16.4%, and to optic canal in 29.7%. Between the age and gender groups DNS was highest in young adult female group (35.9%). CB is less frequent in senior adults than the other age groups. Crista galli pneumatization was higher among senior adult age group, 14.3%. The paradoxical middle turbinate was found in 9.5%, bilateral in 7%, and no gender or age group variations were seen. Uncinate process was attached to lamina papyracea in 73.7%, middle turbinate 17.4% (22.4% among females), skull base 8.9% (10.3% among males). Overall, no significant age group variation was observed (Sumaily, Aldhabaan, & Hudise, 2018).

The nasal septum, a partition between the nasal cavities, which is formed by cartilages and bones. The nasal septum divides the nasal cavity into two asymmetrical halves because of its deviation to one side which is called as DNS. The DNS may be either congenital or traumatic. DNS is a common disorder that up to 62% of the population use to encounter with this condition, and its role in the pathogenesis of sinusitis still remains uncertain (Shoib & Viswanatha, 2016). In 2015 DNS was detected in 52 subjects out of 100. The incidence of deviations onto the right and left side were almost identical with a slight predominance onto the right side, with distribution of 27% variation towards the right and a 25% variation towards left side (Chaitanya, Suseelamma & Singh, 2015).

The word concha bullosa (CB) was devised by Zuckerlandl in 1862 to describe pneumatization of the middle nasal turbinate, and on the basis of initial anatomical dissections its incidence was reported as 9% to 20%. The importance of this anatomic variant of nasal turbinate lies in the probable secondary deformity of the nasal turbinate, that increases the possibility of middle meatus obstruction and leading to recurrent ethmoid sinus infection. An obstructed OMC was observed in 148 patients (53%), followed by CB in 98 patients (35%). The author concluded that bony variants do not upsurge the risk of sinus mucosal infection. But, anatomic variants with a potential influence on operative safety occur commonly and it is required to sought it out specifically as part of preoperative identification (Nouraei et al., 2009).

Bolger et al., (1991) revealed three types of nasal middle turbinate pneumatization that includes the vertical lamella was pneumatized in 46.2% of subjects ("lamellar cell") in the inferior bulbous portion in 31.2% of cases and pneumatization in the entire middle nasal turbinate was seen in 15.7% of cases ("true" CB). Unilateral or bilateral CB was seen in 49.3% of subjects in the present series. According to data from the literature, the incidence of positive CT findings for CB varies from 14% to 62% (Fadda et al., 2012).

An interesting anatomical region was defined by Schaeffer in 1916 as the “nasofrontal region”. Historically, the first detailed explanation of the various cells present in this region was described in 1941 by van Alyea, who quoted the term “frontal recess” rather than “nasofrontal duct.” Van Alyea termed the name “frontal cells” with its broader meaning to discuss the various types of ethmoidal cells which are pneumatizing in this area. And this includes the frontal cells which are also called as the frontoethmoidal cells, agger nasi cells, interfrontal sinus septal cells, supraorbital cells and other cells include the suprabullar cells and the frontal bulla cells (Eweiss & Khalil, 2013; Ozdemir & Arslan, 2018).

The agger nasi cells are considered to be the most constant residents of the frontal recess. And it was reported in 1991 that agger nasi cells exist in 98.5% of patients (Bolger et al., 1991). The term frontal cells or frontoethmoidal cells is currently used to describe a group of anterior ethmoidal cells that have been classified into 4 types. Type I is that in which the single frontal cell lies above an agger nasi cell. Type II is that in which a tier of cells in the frontal recess above the agger nasi cell are present. Type III involves a large cell pneumatizing from the frontal recess into the frontal sinus. Type IV is that in which a cell is totally isolated within the frontal sinus (Bent, Cuilty-Siller & Kuhn, 1994). The frontal cells have been observed in 20–41% of PNS (DelGaudio, Hudgins, Venkatraman, & Beningfield, 2005).

Various ethmoid cell variation may be present in the frontal recess, affecting its architecture that is assessed by the patency of boundaries and walls of the adjacent structures for instance frontal cells that are classified into 4 types, Type 1: noticed in 37% of frontal recesses; described as single ethmoid cell situated anterior to frontal recess and above the agger nasi cell. Type 2: observed in 18% of subjects which is defined as two or more than two ethmoid cells placed anterior to recess plus above agger nasi cells. Type 3: detected in 6-8% of the cases in which single voluminous cell noticed above agger nasi cell. Type 4: very rarely found which is observed in 2-4% of the patients, defined as ethmoid cell is observed within frontal sinus with no communication with agger nasi cell (Thimmappa et al., 2014).

The type of posterior ethmoidal cells which originates from supero-lateral side of sphenoid sinus are known as onodi or sphenoethmoidal cells (Lund et al., 2014). In 2014 the prevalence of sphenoethmoidal cells was noted as 62.9-69.7%. The reported incidence based on ethnic subgroup analysis was more prevalent in Asian population (70%), followed by African (45%), American (58%), Hispanic and White (41%). The reported prevalence between men (48%) and women (44.5%) was almost equivalent. It is vital for various surgeons of medical fields to look for the presence of onodi cells before going for endoscopic sinus procedures and skull base surgeries as these cells are in close relation with second cranial nerve which is optic nerve and any trauma to it will lead to unwanted harmful complications which will be very miserable for the life of individual (Tomovic, Chan, Esmaeili, Liu & Eloy, 2012).

In 1765 Albrecht von Haller (1708-1777) first identified haller cells, hence named as haller cells. Later the first anatomist who described these cells, added a new terminology for standard and descriptive nomenclature of anatomical terms. Therefore, these were alternatively called as infraorbital anterior ethmoidal cells because of its origin from anterior ethmoidal cells. In addition to this these are located medially in the orbital floor. The type of anterior ethmoidal cell that arises near the orbital floor that can obstruct the adjacent maxillary sinus ostium and infundibulum are termed as haller or infraorbital cells. These infraorbital cells pneumatize below the orbital floor and lateral to lamina papyracea. The reported prevalence of haller cells was relatively high (60%) (Ali, Sansare, Karjodkar, Vanga, Salve & Pawar, 2017; Friedrich, Fraederich, & Schoen, 2017; Mathew, Omami, Hand, Fellows, & Lurie, 2013; Pekiner, Borahan, Dumlu, & Özbayrak, 2014).

The pneumatization of uncinate process (UP) called uncinate bulla refers to an aeration of air cells into uncinate process. From ethmoid bone uncinate process projects to the ethmoid process of inferior concha of nose. This anatomical variant of sinonasal region is observed quite rare, as compared to other anatomical variants of sinonasal area. The reported rate of UP pneumatization in former studies has been stated as 0.4–9 %. Research revealed most authors believe that anatomical variations of PNS region might be a reason for recurrent sinusitis. Further, the virtual importance of anatomical variants of sinonasal region is still a staple of discussion, and consensus has not been reached yet (Kaygusuz et al., 2014). The close proximity of PNS to important structures and neurovascular bundle such as optic nerve, orbit, skull base, and internal carotid artery, stresses on the need of identification of anatomical variations of PNS in order to avoid the serious complications of surgical procedure (Kumar et al., 2016).

The structural morphology of paranasal sinuses shows vast diversity. They all vary in size, shape, morphology and count of the septa present, as in sphenoid sinus the MS which is main septum, and AS which is additional septum. The sphenoid sinus is related with important anatomical structures via their walls, includes both vascular and nervous also other neighboring relations, in addition to the anatomical organization of the sphenoid sinuses, it is of great significance in the various surgical procedures such as FESS. CT imaging technique is one of the most accurate methods for imaging of the paranasal sinuses to visualize various structures along with their extent and depth. This method allows doctor to distinguish the variations in the anatomical relations of the PNS, due to the obvious clear-cut illustration of the bony structures (Jaworek-Troć et al.,2018).

Sphenoidal sinus variation is broadly encountered in a common surgical procedure called functional endoscopic sinus surgery. FESS is one of the best choices in a variety of surgeries such as endoscopic orbital surgery, sinonasal tumors. Various nerves for example optic nerve and vessels such as internal carotid artery and many other structures are present near sphenoid sinus which are at danger during surgical procedure. These structures will be at risk of injury during surgery because of anatomical variations which includes protrusion, dehiscence, pneumatization. CT scan imaging is useful technique for the detection of PNS anatomical variants. Besides diagnostic value, CT scan imaging is valuable for risk assessment factors produced by anatomical variations of PNS (Joghataei et al., 2019).

The second cranial nerve (CN-II) which is optic nerve was categorized into four types based on their association with the adjacent sphenoid sinus and their course. Out of four types, type one was more frequently observed on left side (84%) and on right side (76%), whereas type IV CN-II involvement was infrequent. This prevalence rate highlights the requirement of early detection and identification of anatomical variants along with timely intervention in order to prevent disease complications. The incidence rate of dehiscence of lamina papyracea, cribriform plate and carotid canal wall is low but it is very important to be evaluated, author observed that only 2% of patients had dehiscence of lamina papyracea whereas cribriform plate and carotid canal wall dehiscence was not found in any of the subject (Reddy, Kakumanu, Kondragunta, & Gandra, 2018).

Leunig et al., (2008) observed anatomic variants of sinonasal region with the help of multiplanar computed tomography. Author reported most of the anatomical variants were more frequent in frontoethmoidal cells. And out of four types of Kuhn cells, type-I was more prevalent and type-IV was least common. The agger nasi cells were more prevalent with frequency of 80%, CB-22%, haller cells-16%, pneumatized uncinate process-8.8% and onodi cells-8.4% was reported (Leunig, Betz, Sommer & Sommer, 2008).

In 2019 it was observed in a study in which overall 120 participants were included in the research. Out of 120 subjects, 96(80%) participants had at least one anatomic variant. Among the anatomical variations studied, DNS was the most common anatomic variation found, followed by CB seen in 44(36.67%) patients, large ethmoid bulla (32.50%), paradoxical middle turbinate (23.3%), hypertrophied uncinate process (20%), agger nasi cells (16.67%), haller cells (12.5%) and onodi cells (6.67%). 86(71.67%) out of 120 subjects had bilateral chronic rhinosinusitis (CRS) while 34(28.33%) had unilateral CRS. Out of 86 subjects with bilateral CRS, 38(44.18%) participants had bilateral involvement, followed by left sided involvement seen in 21(24.44%) patients, right sided in 17 (19.76%) patients and no variation in 10(11.62%) subjects. The sinonasal area has broad range of anatomical variations. This study concluded that computed tomography is important investigation tool to evaluate and detect anatomical variations of nasal cavity and PNS since the rate of anatomical variants is very high in subjects suffering from CRS (Gupta et al., 2019).

Liu et al., (1999) stated that almost 81.14% subjects had anatomical variations. And out of that more prevalence rate of deviation of uncinate process (45.27%), pneumatized middle nasal turbinate (34.85%), and large ethmoidal bulla (30.30%) were reported. Along with these findings less common presence of agger nasi cells (0.70%) and haller cell (1.00%) were observed. Correlation between various anatomic variants of sinonasal region and chronic sinusitis was found to be significant ($p < 0.01$). The existence of anatomical variations in OMC region is very common. And these anatomic variations can be one of the causative factors of chronic sinusitis. Therefore, before planning for any kind of surgical procedure proper handling of these anatomic variations is always recommended (Liu, Zhang, & Xu, 1999). The clinical correlation of the disease symptoms and radiological CT observations has proved to be beneficial in assessing the severity of the symptoms which enables the health facilitator to improve disease management and provide benefit to the individual (Nair, 2009). It was stated in some studies that no specific association occurs between the anatomical variants and clinically significant rhinosinusitis, also highlighted the other local causes including, systemic, environmental factors or intrinsic mucosal disease in the pathogenesis of rhinosinusitis (Jun Kim et al., 2006; Lerdlum & Vachiranubhap, 2005).

Whatever may be the diagnosis, but for understanding of anatomical relations of paranasal sinuses, CT Scan of Para nasal sinus is mandatory before performing sinus surgery. This is to avoid chance of complications while performing the procedure. Patients having history of chronic sinusitis over a period of months or years, and who are not responding to medical therapy, computed tomography should be performed for the possible identification of anatomical variants. In order to prevent harmful complications such as cerebrospinal fluid (CSF) leak, meningitis, or blindness, which will decrease the burden of disease, patient disability and patient morbidity, so a detailed knowledge of the possible anatomical variations is essential (Gouripur et al., 2017).

Anatomical variations of nasal cavity and paranasal sinus region which are clearly visible on CT-scan possess critical significance for it may increase risk of injury during surgery or predispose to certain pathologies. Overall, total 143 subjects were evaluated out of which 48.3% were male and 51.7% were female with a mean age of 35.27 years, age ranging from 16 to 75 years. The recorded frequency of major sinus anatomic variations of sinonasal region were: Agger nasi cell in 56.7%, Haller cell in 3.5%, Onodi cell in 7%, DNS in 63%, CB in 35%. The overall frequency of anatomical variations in sinonasal region may be associated to race and heredity (Talaiepour, Sazgar, & Bagheri, 2005).

The precise knowledge of anatomic variants of sinonasal region is key in the preoperative evaluation of patients who are planned for sinus surgery. The complex variable anatomy of nasal cavity and sinuses create technical problems during surgery. Some anatomic variants are considered as risk factors for various sinus surgical procedures, the detailed knowledge of variant anatomy of the individual can contribute to better surgical outcomes. This extended detailed anatomic knowledge is key for preoperative evaluation as some of the anatomic variants are closely related to various important structures and can increase the complication rates. Complications happen for variety of reasons, even failure to identify certain anatomic variations of sinonasal region is one of the most important mistakes. The communication between the surgeon and the radiologist is critical. In most of the patients more than one sinus was involved and most commonly affected combination of sinuses were frontal and ethmoid sinus with frequency of 60%. Ethmoid sinus is close to orbital cavity so any infection can easily spread into the orbit or intracranially (Sajid et al., 2011).

Coronal plane computerized tomographic (CT) scanning has markedly improved the imaging of complex PNS anatomy as compared to sinus radiographs. Increasingly subtle bony anatomical variations and mucosal abnormalities of this region are being detected. Computerized tomography (CT) offers the gold standard in terms of imaging the extent of disease pathology and the fine detailed anatomy of paranasal sinus. Neither plain X-rays nor Magnetic Resonance Imaging (MRI) offer optimal information in this respect (Bagul, 2016).

CT imaging is important to evaluate various pathologies of nasal cavity and PNS. CT imaging allows to assess the fine bony details related to PNS, anatomical variants of PNS, and disease progress of PNS. Coronal high-resolution CT of the sinuses has become widely accepted as a necessary part of the preoperative evaluation of patients scheduled for FESS. CT scanning is better in identifying anatomical landmarks of PNS preoperatively and thereby reduces the complications of FESS. CT imaging technique is now established as the overall best method for evaluation of patients who are suspected of having a complex anatomy and any aggressive lesion of the paranasal sinuses (PNS) (Kandukuri & Phatak, 2016).

Literature has revealed that the conventional radiographs are of limited diagnostic use in evaluation of PNS diseases and modern imaging techniques like CT and MRI provide greater detail about the exact location and the extent of PNS disease also, it helps in better understanding of complex anatomy, diagnosis and surgical planning of the sinuses. It is also stated that CT is better than MRI in knowing the finer bony details, anatomical variations and fibro osseous lesions of PNS (Yousef et al., 2014). CT scan imaging and nasal endoscopic investigation are progressively being used in diagnosing and treating number of patients having rhinosinusitis. Though CT scan accurately depicts the sinus pathology along with complex anatomy but its usage as a proxy in evaluating the symptom severity of patients is controversial (Nair, 2009).

Now a days increasing interest in FESS has put the anatomy of nasal cavity and paranasal sinuses on spotlight. In recent years research about correlation between anatomic variations of sinonasal region and sinusitis has been increasing in order to determine the clinical significance of anatomic variants to prevent sinus mucosal pathologies, but still it is a matter of discussion. It is argued by several authors that some anatomic variants of sinonasal region can cause obstruction of sinus drainage pathway, therefore becoming the reason for various sinus mucosal infections (Abreu et al., 2019).

Currently the modality of choice for evaluation of paranasal sinuses and its nearby structures is computed tomographic imaging. This imaging technique displays accurate information of both bony and soft tissues details along with extent of disease within paranasal sinuses including adjacent structures. In contrast to ordinary radiography, CT imaging can undoubtedly display the fine bony anatomy and variations of the sinuses and OMC channels. The research showed that significance of anatomical variants of sinonasal region is still controversial. Majority of authors believe that various anatomic variants can cause some way for occurrence of recurrent rhinosinusitis (Rasul, Abdullah & Ali, 2018).

Correlation or clinical significance of various anatomical variations of sinonasal region related with several sinus pathologies such as in 62% of symptomatic subjects had at least one anatomic variant of sinonasal region, against 11% of the healthy control group subjects (Zinreich, 1993).

It was concluded that use of CT scan is the most accurate approach in understanding the anatomical variations and diagnosing the diseases of PNS. Surgeon must keep in mind that, remove only as much as required and preserve as much as possible has been the most important instruction of FESS. The anatomy of the nasal cavity and PNS is variable in every individual. CT is the investigation of choice particularly for the patients who are scheduled for FESS, assisting the ENT surgeon to understand the anatomy affecting the paranasal sinus region. Thus, it is termed as ‘‘ROAD MAP OF FESS’’. The paranasal sinuses are critically important having complex anatomical variations, and variable anatomical relations, hence CT scan is advisable to all patients who are undergoing surgical intervention, in order to prevent dreadful complications (Mokhasanavisu, Singh, Balakrishnan & Kadavigere, 2019). The detailed workup of some previous studies from 2015 to 2019 are compiled in Table-2.1.

Table: 2.1 Previous studies (2015-2019)

S#	Author and year	Study type, (n), Methodology, Statistical analysis (test)	Gender (M/F)	Age group	Outcome/Association with sinusitis
1	Tiwari & Goyal (2015)	Prospective cross sectional, n=85 CT-scan PNS and nasal endoscopy, Not mentioned	58 (M) 27 (F)	Divided into five groups 10-20 21-30 31-40 41-50 >50 years	CB=76.4% DNS=88.2% Paradoxical MT=10.5% Prominent bulla=63.5% Agger nasi=7% Haller cells=3.5% Abnormal UP= 10.5% Onodi cell=1.6% Septum pneumatization=8.2% Others=3.5% No association
2	Suri, Janardan & Parmar, (2016)	Prospective cross sectional, n=120 CT-scan, Fischer's exact test	Both sex	Adult of all age group (younger than 18 were excluded)	DNS=75% CB=41.6% UP deviation=12.5% Paradoxical MT=8.3% Agger nasi=6.6% Onodi cell=4.1% Haller cell=1.6% Pneumatized Vomerine Bone=1.6% Significant association
3	Alsowey et al., (2017)	Prospective study, n=240	138 (M) 102 (F)	20-61 years with the	DNS=48.8% Agger nasi= 30.6% CB=30.6%

		MSCT scanner and endoscopic evaluation, McNemar test and the kappa (K) statistic		mean age of 40.5 years	Haller cells=11.2% UP variations=18.1% Large ethmoid bulla=10% No association
4	Espinosa, Genito & Ramos, (2018)	Retrospective study, n=60 CT -scan, Not mentioned	43 (M) 17 (F)	Adult (>18 years old)	Agger nasi =78.3% Haller cells= 41.6% DNS=20.0% CB= 11.7% Significant association
5	Mathuram et al., (2019)	Prospective study, n=200 128-MDCT, Fischer's exact test	116 (M) 84 (F)	11-60 years	DNS=73.44% Septal spur=46.88% CB= 23.44% Agger nasi=29.69% Haller cells= 3.13% Onodi cells= 7.81% Pneumatized UP=3.13% Paradoxical MT= 21.88% No association

CHAPTER 3

METHODOLOGY

3.1. Study design

Prospective cross-sectional study design is implemented in the current work. This research is a human based study and time period for this research work was six months January-June 2020. This work was conducted at Radiology Department of PNS Shifa Hospital Karachi. Initially ethical approval from Ethical Review Committee (ERC) of Bahria University Medical and Dental College (BUMDC) for this project was obtained. The subjects who visited the ENT Department of PNS Shifa Hospital Karachi for the treatment of sinusitis and were referred to Radiology Department for radiological investigation were considered for this research after fulfilling the inclusion criteria and written informed consent.

3.2 Subjects

Human, symptomatic subjects of sinusitis were selected with age ranges from 18 to 60 years.

3.3 Setting

PNS Shifa Hospital Karachi. The patients coming to the Radiology Department referred from ENT Department of PNS Shifa Hospital Karachi were taken as study participants after their willing consent.

3.4 Inclusion criteria

- Age ranges from 18 to 60 years
- Both genders
- Symptomatic subjects of sinusitis (nasal obstruction, headache, facial pain, rhinorrhea)
- Radiological features: mucosal thickening of the sinuses greater than 1 mm measured on CT-scan

3.5 Exclusion criteria

- Age below 18 years
- Radiological features: mucosal thickening of sinuses less than 1 mm measured on CT-scan
- Sinonasal polyposis
- Fungal sinusitis
- Sinonasal malignancy
- Pregnant females
- Previous sinus surgery
- Facial trauma

3.6 Duration of study

(a) Individual study: Period 2 hours per case

(b) Total period of study: 6 months

3.7 Sample size estimation

The present study "Anatomical variations of nasal cavity and paranasal sinuses in sinusitis on CT-scan", sample size was estimated using the method of sample size for frequency in a population on www.openepi.com which is an open source calculator, version 3-SSPropor using following equation;

Sample size $n = [DEFF*Np(1-p)]/ [(d^2/Z^2_{1-\alpha/2}*(N-1) +p*(1p)]$

Using 10% prevalence of anatomical variants of sinonasal region (Alsowey, et al., 2017) in general population. Sample size of 65 at 95% confidence interval with population size (N): 120, hypothesized % frequency of outcome factor in the population (p): 10%+/-5 with a confidence limits as % 100 (absolute +/-%) (d):5% and design effect (for cluster surveys-DEFF):1 was obtained. The sample size was found to be as 65.

3.8 Sampling technique

Non-Probability convenience sampling technique was applied for this research project. As all the subjects were selected non randomly so non probability sampling process was applied for the data collection of this current study. The samples were selected for a specific purpose with predetermined basis of selection which was based on inclusion and exclusion criteria of the study.

3.9 Human subjects and consent

The consent forms for subjects were designed in both languages i.e. English and Urdu which includes all the information about the research work. The written informed consent was obtained from all the subjects. The consent forms are attached as Appendix C.

3.10 Materials used (Drugs/ Chemicals/ Proforma /Questionnaire/any other)

The materials which were used to conduct this study include consent forms i.e. English and Urdu, CT scan machine (Prime Aquilion-160 slice Toshiba), CT- reporting room (Figure 3.1, Figure 3.2), CT scan reports and Questionnaire.

The consent forms and questionnaire are attached as Appendix C and D

Figure 3.1 CT scan machine (Prime Aquilion-160 slice Toshiba) (PNS-Shifa Hospital Karachi)

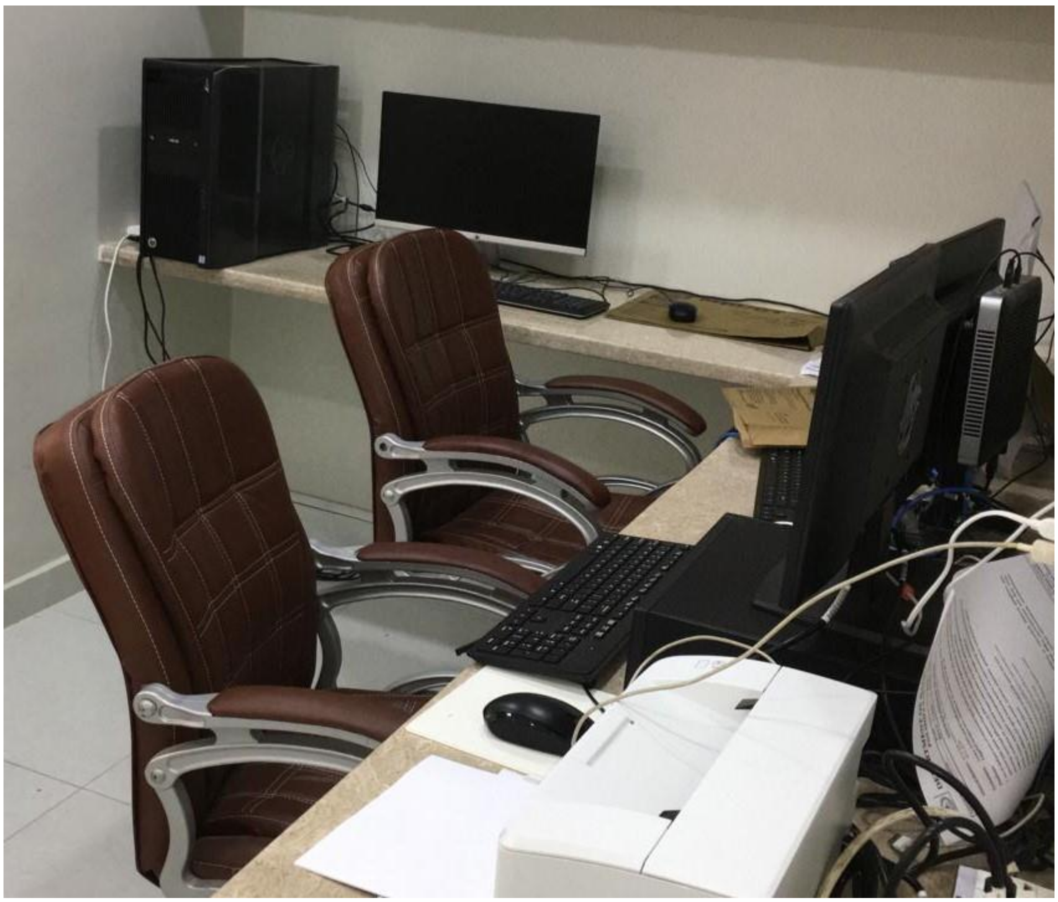


Figure 3.2 CT scan reporting room (PNS-Shifa Hospital Karachi)

3.11 Parameters of study

The subjects of this prospective study include the patients which were fulfilling the inclusion criteria after written informed consent and following were the parameters of the study.

Symptomatic subjects of sinusitis and findings of CT-scan of the Paranasal Sinuses were included. And in all cases, following anatomical variants were investigated:

(1) Nasal septum: septal deviation, septal bony spur

(2) Turbinate: superior concha bullosa, middle concha bullosa, paradoxical (false) middle concha, hypoplasia, and secondary middle concha

(3) Uncinate process: deviation of the upper edge, pneumatization

(4) Ethmoid air cells: agger nasi cells, haller cells, ethmoid bulla, onodi cells

(5) Other variants included: hypoplasia of the maxillary sinus, maxillary septa, hypoplastic frontal sinus and asymmetry of both cavities of the sphenoid sinus. And related anatomy of the paranasal regions such as aerated crista galli was also investigated.

3.12 Protocol of study

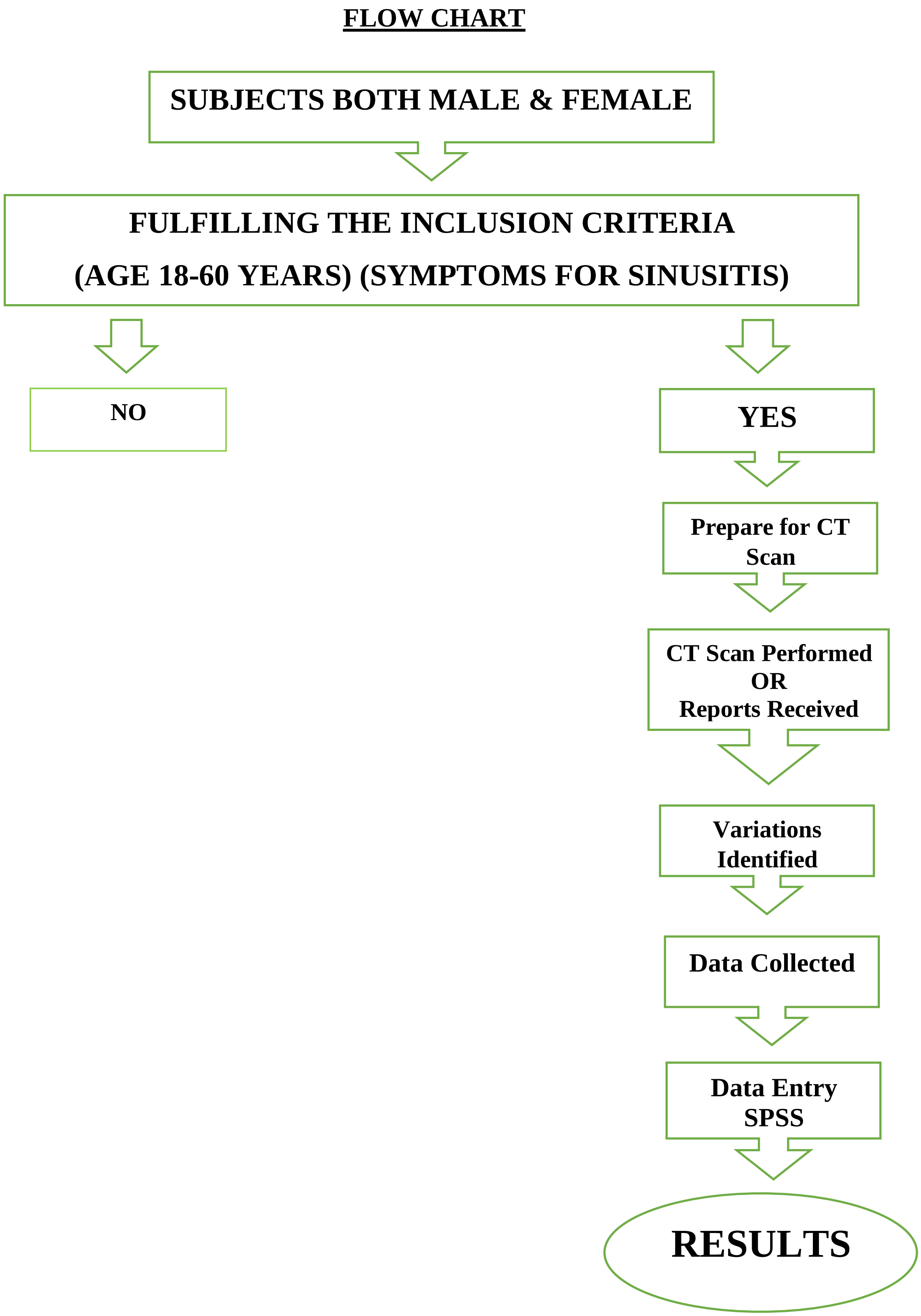
The study was conducted after receiving Ethical approval from ethical review committee (ERC) of Bahria University Medical and Dental College (BUMDC) Karachi. The data was collected at Radiology Department of PNS Shifa Hospital Karachi and duration of this study was six months. Subjects meeting the inclusion criteria were considered after written informed consent. Detailed history regarding their demographic data, age, and symptoms of sinusitis which included nasal obstruction, headache, facial pain and rhinorrhea was taken from all subjects.

After history taking and written informed consent, patients were prepared for CT Scan of Paranasal Sinuses (PNS) in the coronal plane, supplemented by axial views. CT scan of Prime Aquilion-160 slice of Toshiba company was used. All CT-scan images were observed in CT reporting room of Radiology Department of PNS Shifa Hospital Karachi and positive findings were noted on questionnaires.

For coronal imaging, patients were positioned in prone position. Hard palate was taken as reference point, the plane of section was perpendicular to the hard palate. Direct scans of 3 mm in thickness were made, from the anterior walls of the frontal sinuses to the posterior wall of the sphenoid sinus.

For the axial scans, slice thickness was 3 mm thick, the orbitomeatal line was taken as reference point while the patient was lying in supine position. The exposure settings used were 120 kV and 80 mAs.

3.13 Algorithm of study



3.14 Statistical analysis

Statistical analysis was done using the Statistical Package for Social Science (SPSS) software version 23.0. All continuous variables were presented as mean ± Standard deviation. All discrete variables were presented as frequency and percentages. Symptoms, variants and gender were also compared to assess the association by using Chi-square test and Fischer exact test for getting significance. The Fischer exact test was applied when expected frequency in any cell was less than 5. The p-value ≤ 0.05 considered to be statistically significant.

CHAPTER 4

RESULTS

A total of 80 patients were included in this study. Mean age of participants was 44.6±18.5 years. There were 53 (66.3%) male and 27 (33.8%) female. Overall, 100% prevalence of anatomic variants was observed in symptomatic subjects of sinusitis. Most common symptom was found to be headache 39 (48.75%), followed by nasal obstruction observed in 21 (26.25%), Rhinorrhea was seen in 15 (18.75%) and Facial pain found in 5 (6.25%) patients (Figure 4.1, Table 4.1).

Most common anatomical variant was observed to be septal deviation seen in 47 (58.8%) (Figure 4.2), septal bony spur was found in 32 (40%) (Figure 4.2), Middle concha bullosa was seen in 37(46.3%) (Figure 4.3), Agger nasi cells was observed in 45 (56.3%), Onodi cells was seen in 10 (12.5%), Haller cells was noticed in 9 (11.3%), Hypoplastic frontal sinus was observed in 25 (31.3%) and Asymmetry of both cavities of the sphenoid sinus was seen in 15 (18.8%) patients (Figure 4.4, Figure 4.5 Table 4.2).

Association of gender was compared with symptoms. There were 16 (30.2%) male and 5 (18.5%) female having symptoms of nasal obstruction with non-significant p-value 0.262. Symptoms of headache was seen in 26 (49.1%) male and 13 (48.1%) female with non-significant p-value 0.939. Facial pain was observed in 2 (3.8%) male and 3 (11.1%) female with non-significant p-value 0.329. Rhinorrhea was found in 9 (17.0%) male and 6 (22.2%) female with non-significant p-value 0.763 (Figure 4.6, Table 4.3).

Association of gender was also compared with different variants. Septal deviation was observed in 32 (60.4%) male and 15 (55.6%) female with non-significant p-value of 0.679. Septal Bony Spur was observed in 23 (43.4%) male and 9 (33.3%) female with non-significant p-value 0.385. Middle Concha Bullosa was found in 23 (43.4%) male and 14 (51.9%) female with non-significant p-value 0.473. Agger Nasi cells was found in 32 (60.4%) male and 13 (48.1%) female with non-significant p-value 0.297. Haller cells variant was found in 5 (9.4%) male and 4 (14.8%) female with non-significant p-value 0.471. Onodi Cells were seen in 6 (11.3%) male and 4 (14.8%) female with non-significant p-value 0.655. Hypoplastic Frontal Sinus was found 18 (34.0%) in male and 7 (25.9%) female with non-significant p-value 0.463. Asymmetry of Both Cavities of the Sphenoid Sinus found in 8 (15.1%) male and 7 (25.9%) female with non-significant p-value 0.241 (Table 4.4).

Association between gender and involvement of sinuses was also determined. In Maxillary Sinus Right there were 8 (15.1%) male and 8 (29.6%) female with non-significant p-value of 0.124 whereas in left Maxillary Sinus there were 10 (18.9%) male and 4 (14.8%) female with non-significant p-value of 0.652. Ethmoid Sinus Right were observed in 12 (22.6%) male and 2 (7.4%) female with a non-significant p-value of 0.09 whereas in left Ethmoid Sinus there were 11 (20.8%) male and 3 (11.1%) female with non-significant p-value of 0.283. Frontal Sinus right presence was seen in 6 (11.3%) male and no female was observed with not-significance p-value 0.069. Frontal sinus left was seen in 5 (9.4%) and 1 (3.7%) female with non-significant p-value 0.358. Sphenoidal Right sinus were seen in 5 (9.4%) male and 1 (3.7%) female with not-significant p-value 0.358 however in left Sphenoidal sinus there were 5 (9.4%) male and 2 (7.4%) female with not-significant p-value 0.762 (Table 4.5).

Association of symptoms and anatomical variants were also compared to see the significance. Nasal obstruction was seen in agger nasi cells right and left both with significant p-value of 0.014. When nasal obstruction was compared with onodi cells right and left both with a non-significant p-value 0.075 and 0.098 respectively. When Nasal obstruction was compared with concha bullosa right and left both no significant association was seen p-value 0.868 and 0.265 respectively. When Nasal obstruction was compared with Haller cells no significant association was found with p-value of 0.608 and 0.884 respectively for right and left. Nasal obstruction was compared with DNS right and left there were no significant association found with p-value of 0.072 and 0.898 respectively. Nasal Obstruction was also compared with DNS with spur right and left no significant association found with p-value of 0.738 and 0.34 (Table 4.6). Nasal obstruction was compared with Posterior Nasal Septal Air Cells (Figure 4.7) and aerated crista galli, no significant association observed with p-value of 0.682 and 0.439 respectively (Table-4.7).

Headache was associated with agger nasi cells right and left both with significant p-value of 0.026. When Headache was associated with onodi cells right and left both with a non-significant p-value 0.941 and 0.744 respectively. When Headache was associated with concha bullosa right and left both no significant association was seen p-value 0.262 and 0.862 respectively. When Nasal obstruction was associated with Haller cells no significant association was found with p-value of 0.655 and 0.209 respectively for right and left. Headache was associated with Posterior Nasal Septal Air Cells no significant association observed with p-value of 0.432. Headache was associated with DNS right and left there were no significant association found with p-value of 0.890 for both right and left. Headache was also associated with DNS with spur right and left no significant association found with p-value of 0.875 and 0.875 (Table 4.8, Table 4.9).

Facial Pain was correlated with agger nasi cells right and left both with non-significant p-value of 0.091. When Facial Pain was correlated with onodi cells right and left both with a non-significant p-value 0.441 and 0.475 respectively. When Facial Pain was correlated with concha bullosa right and left both no significant association was seen p-value 0.614 and 0.905 respectively. When Facial Pain was correlated with Haller cells no significant association was found with p-value of 0.552 and 0.358 respectively for right and left. Facial Pain was correlated with Posterior Nasal Septal Air Cells no significant association observed with p-value of 0.511. Facial Pain was correlated with DNS right and left there were no significant association found with p-value of 0.378 and 0.155 for right and left. Facial Pain was also correlated with DNS with spur right and left no significant association found with p-value of 0.944 and 0.230 (Table 4.10, Table 4.11).

Rhinorrhea was correlated with agger nasi cells right and left both with non-significant p-value of 0.782. When Rhinorrhea was correlated with onodi cells right and left both with a non-significant p-value 0.534 and 0.609 respectively. When Rhinorrhea was correlated with concha bullosa right and left both no significant association was seen p-value 0.210 and 0.824 respectively. When Rhinorrhea was correlated with Haller cells no significant association was found with p-value of 0.685 and 0.610 respectively for right and left. Rhinorrhea was correlated with Posterior Nasal Septal Air Cells no significant association observed with p-value of 0.588. Rhinorrhea was correlated with DNS right and left there were no significant association found with p-value of 0.764 and 0.215 for right and left. Rhinorrhea was also correlated with DNS with spur right and left no significant association found with p-value of 0.506 respectively (Table 4.12, Table 4.13).

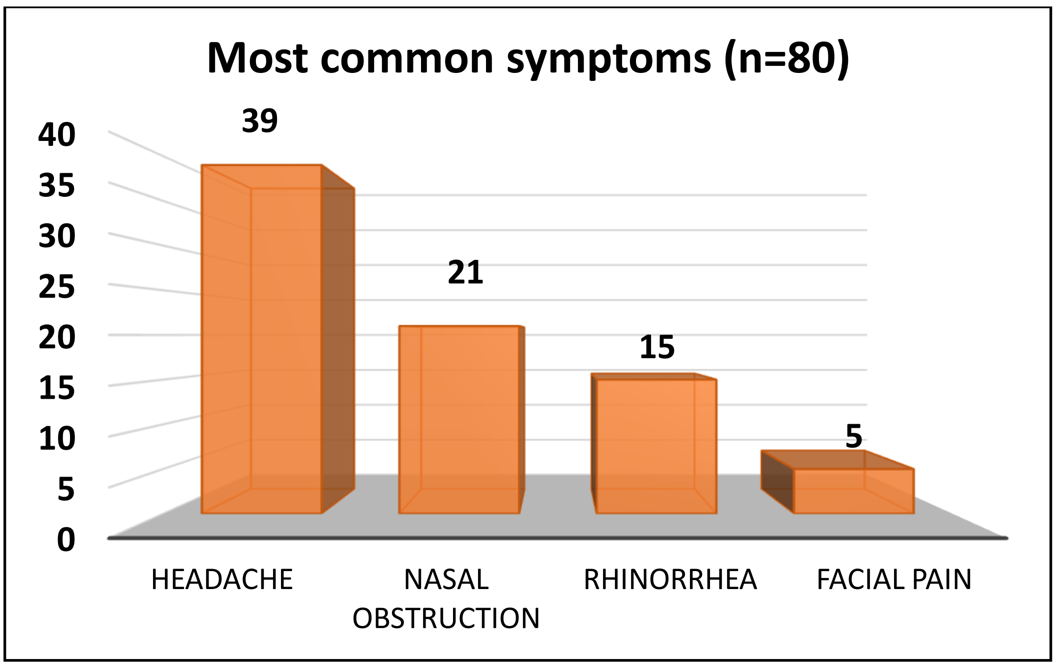


Figure 4.1 Distribution of symptoms among patients

Table 4.1 Frequency of symptoms in Patients with Sinusitis

Most common symptoms	**Number of patients**	**%**
Headache	39	48.75
Nasal Obstruction	21	26.25
Rhinorrhea	15	18.75
Facial pain	5	6.25

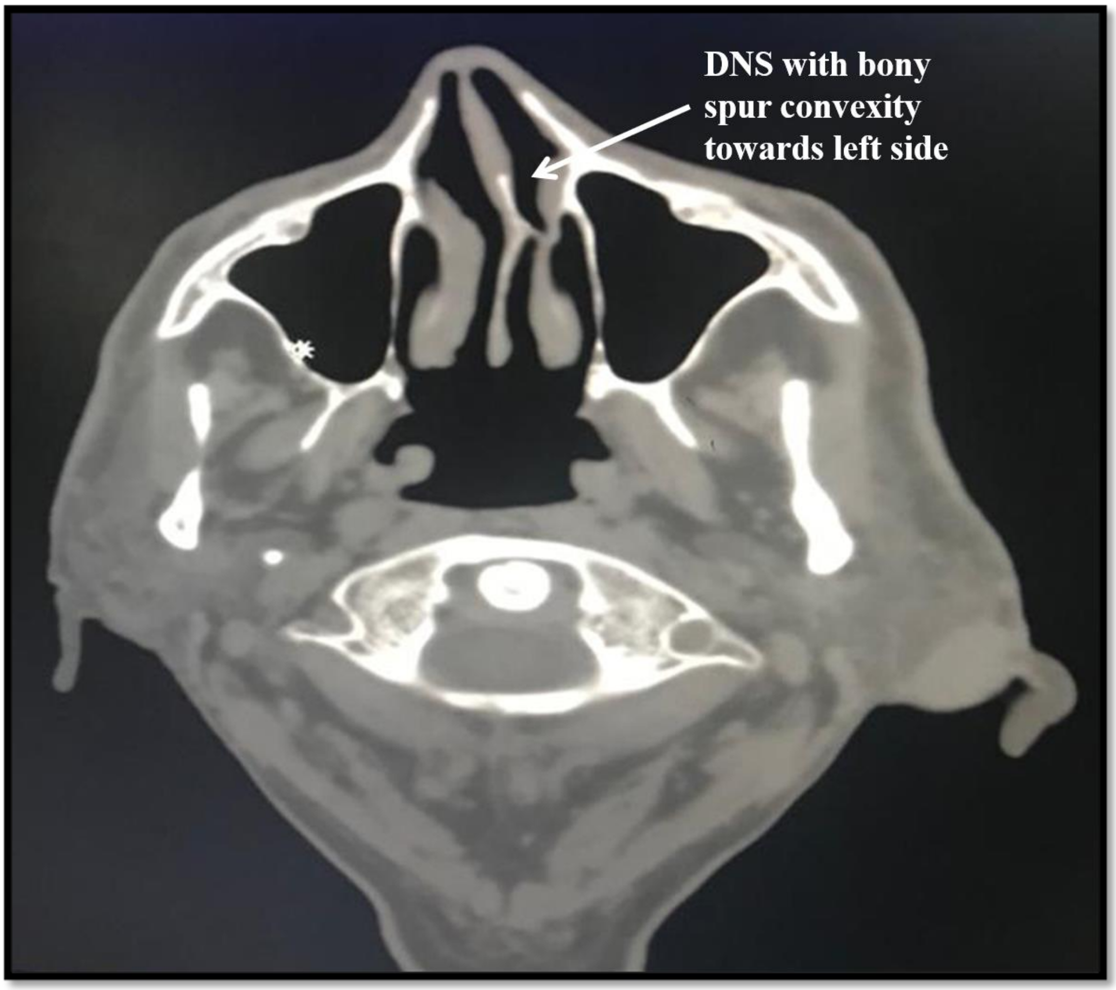


Figure 4.2 Axial view of CT-PNS showing deviated nasal septum (DNS) with bony spur convexity towards left side in symptomatic subject of sinusitis

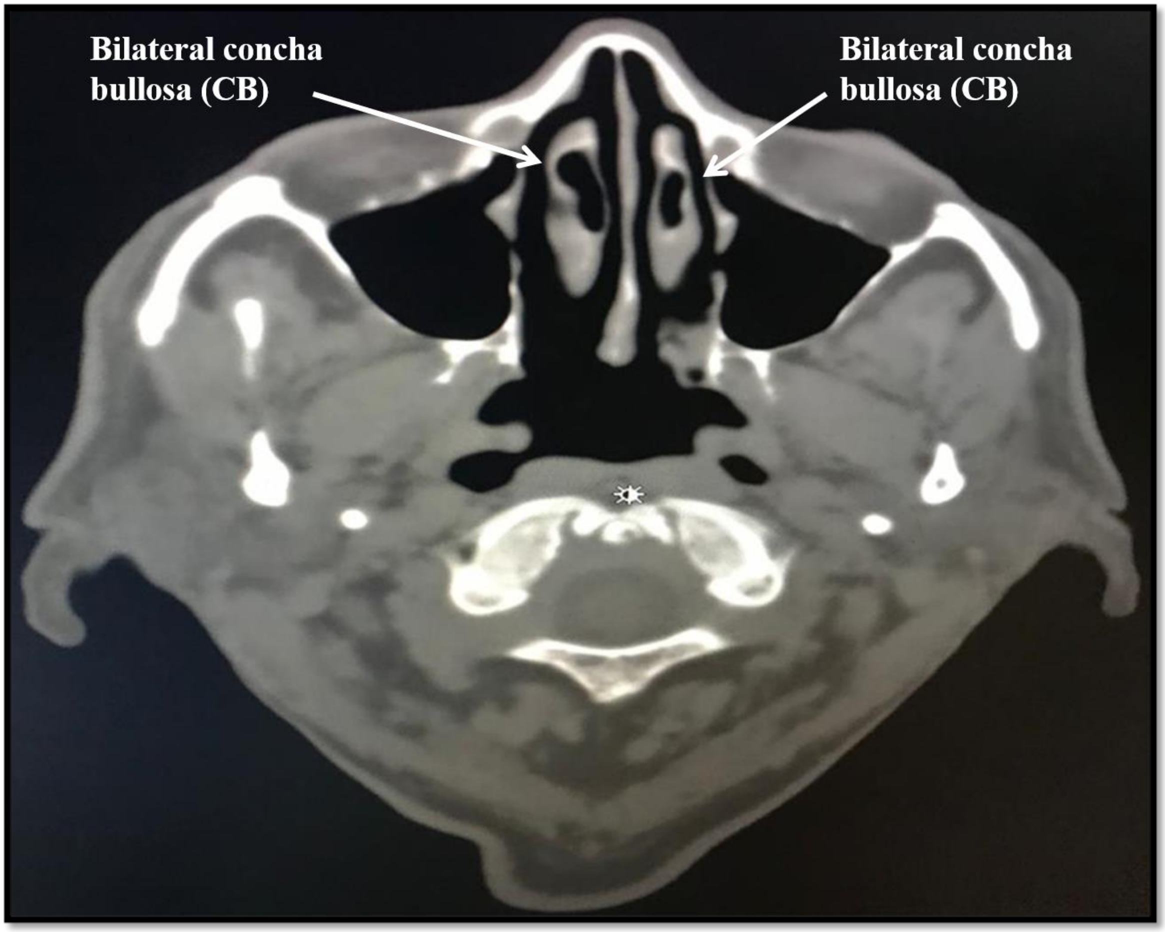


Figure 4.3 Axial view of CT-PNS showing bilateral concha bullosa (CB) in symptomatic patient of sinusitis

Figure 4.4 Coronal view of CT-PNS showing asymmetry in sphenoid sinus cavity (septate sphenoid sinus) in symptomatic patient of sinusitis

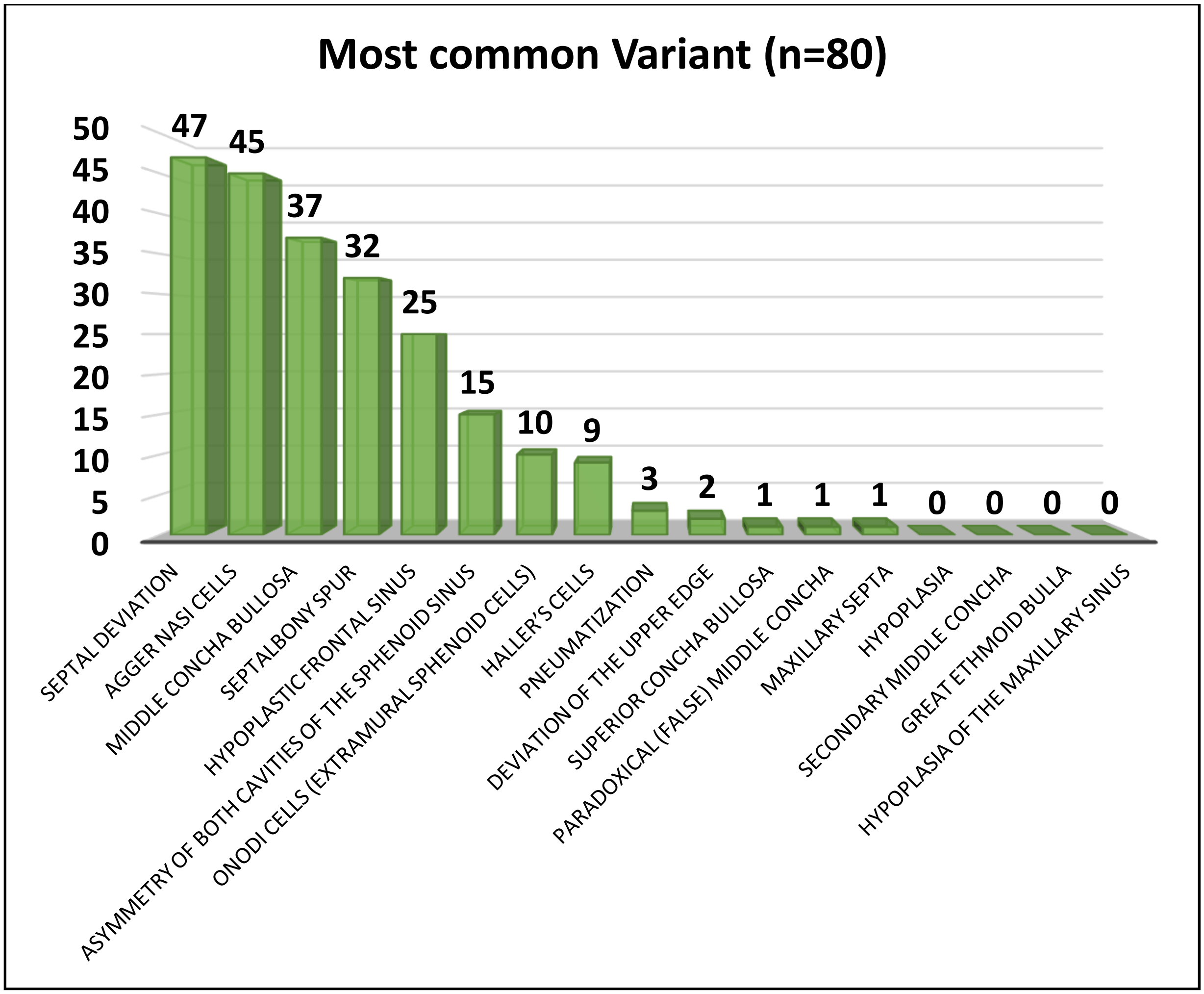


Figure 4.5 Distribution of various anatomical variants of sinonasal region in symptomatic subjects of sinusitis

Table 4.2 Frequency of various anatomical variants in symptomatic subjects of sinusitis

Most common Variant	*No	%
Nasal septum		
Septal deviation	47	58.8
Septal bony spur	32	40
Turbinate		
Superior concha bullosa	1	1.3
Middle concha bullosa	37	46.3
Paradoxical (false) middle concha	1	1.3
Uncinate process		
Deviation of the upper edge	2	2.5
Pneumatization	3	3.8
Ethmoid air cells		
Agger nasi cells	45	56.3
Haller's cells	9	11.3
Onodi cells (extramural sphenoid cells)	10	12.5
Other variants		
Maxillary septa	1	1.3
Hypoplastic frontal sinus	25	31.3
Asymmetry of both cavities of the sphenoid sinus	15	18.8

*number out of 80 subjects

Table 4.3 Association between Gender and Symptoms in patients with Sinusitis

Symptom	Response	Male (n=53)	Female (n=27)	Total	p-value
Nasal Obstruction	Yes	16 30.2%	5 18.5%	21 26.3%	0.262€
	No	37 69.8%	22 81.5%	59 73.8%	
Headache	Yes	26 49.1%	13 48.1%	39 48.8%	0.939€
	No	27 50.9%	14 51.9%	41 51.3%	
Facial Pain	Yes	2 3.8%	3 11.1%	5 6.3%	0.329¥
	No	51 96.2%	24 88.9%	75 93.8%	
Rhinorrhea	Yes	9 17.0%	6 22.2%	15 18.8%	0.763€
	No	44 83.0%	21 77.8%	65 81.3%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

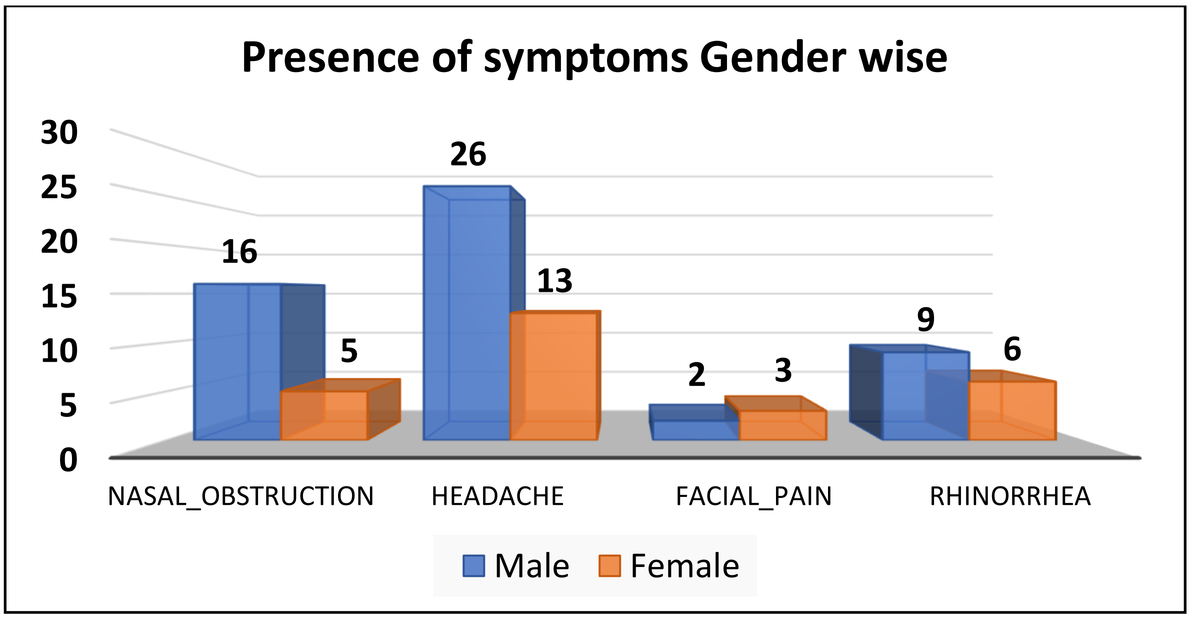


Figure 4.6 Distribution of symptoms gender wise

Table 4.4 Association between Gender and Variants in patients with Sinusitis

Variant	Response	Male (n=53)	Female (n=27)	Total	p-value
Septal Deviation	Yes	32 60.4%	15 55.6%	47 58.8%	0.679€
	No	21 39.6%	12 44.4%	33 41.3%	
Septal Bony Spur	Yes	23 43.4%	9 33.3%	32 40.0%	0.385€
	No	30 56.6%	18 66.7%	48 60.0%	
Superior Concha Bullosa	Yes	1 1.9%	0 0.0%	1 1.3%	0.473¥
	No	52 98.1%	27 100.0%	79 98.8%	
Middle Concha Bullosa	Yes	23 43.4%	14 51.9%	37 46.3%	0.473€
	No	30 56.6%	13 48.1%	43 53.8%	
Paradoxical False Middle Concha	Yes	0 0.0%	1 3.7%	1 1.3%	0.159¥
	No	53 100.0%	26 96.3%	79 98.8%	
Hypoplasia (turbinate)	Yes	0 0.0%	0 0.0%	0 0.0%	p-value cannot be computed
	No	53 100.0%	27 100.0%	80 100.0%	
Secondary Middle Concha	Yes	0 0.0%	0 0.0%	0 0.0%	p-value cannot be computed
	No	53 100.0%	27 100.0%	80 100.0%	
Deviation of the upper Edge (Uncinate process)	Yes	2 3.8%	0 0.0%	2 2.5%	0.307¥
	No	51 96.2%	27 100.0%	78 97.5%	

Pneumatization (Uncinate process)	Yes No	2 3.8% 51 96.2%	1 3.7% 26 96.3%	3 3.8% 77 96.3%	0.988¥
Agger Nasi Cells	Yes No	32 60.4% 21 39.6%	13 48.1% 14 51.9%	45 56.3% 35 43.8%	0.297€
Haller Cells	Yes No	5 9.4% 48 90.6%	4 14.8% 23 85.2%	9 11.3% 71 88.8%	0.471¥
Great Ethmoid Bulla	Yes No	0 0.0% 53 100.0%	0 0.0% 27 100.0%	0 0.0% 80 100.0%	p-value cannot be computed
Onodi Cells (Extramural Sphenoid Cells)	Yes No	6 11.3% 47 88.7%	4 14.8% 23 85.2%	10 12.5% 70 87.5%	0.655¥
Hypoplasia of the Maxillary Sinus	Yes No	0 0.0% 53 100.0%	0 0.0% 27 100.0%	0 0.0% 80 100.0%	p-value cannot be computed
Maxillary Septa	Yes No	0 0.0% 53 100.0%	1 3.7% 26 96.3%	1 1.3% 79 98.8%	0.159¥
Hypoplastic Frontal Sinus	Yes No	18 34.0% 35 66.0%	7 25.9% 20 74.1%	25 31.3% 55 68.8%	0.463€
Asymmetry of Both Cavities of the Sphenoid Sinus	Yes No	8 15.1% 45 84.9%	7 25.9% 20 74.1%	15 18.8% 65 81.3%	0.241€

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.5 Association between Gender and involvement of sinuses

Involved paranasal sinuses	Response	Male (n=53)	Female (n=27)	Total	p-value
Maxillary sinus Right	Yes	8 15.1%	8 29.6%	16 20.0%	0.124€
	No	45 84.9%	19 70.4%	64 80.0%	
Maxillary sinus Left	Yes	10 18.9%	4 14.8%	14 17.5%	0.652¥
	No	43 81.1%	23 85.2%	66 82.5%	
Ethmoid sinus Right	Yes	12 22.6%	2 7.4%	14 17.5%	0.09¥
	No	41 77.4%	25 92.6%	66 82.5%	
Ethmoid sinus Left	Yes	11 20.8%	3 11.1%	14 17.5%	0.283¥
	No	42 79.2%	24 88.9%	66 82.5%	
Frontal sinus Right	Yes	6 11.3%	0 0.0%	6 7.5%	0.069¥
	No	47 88.7%	27 100.0%	74 92.5%	
Frontal sinus Left	Yes	5 9.4%	1 3.7%	6 7.5%	0.358¥
	No	48 90.6%	26 96.3%	74 92.5%	
Sphenoid sinus Right	Yes	5 9.4%	1 3.7%	6 7.5%	0.358¥
	No	48 90.6%	26 96.3%	74 92.5%	
Sphenoid sinus Left	Yes	5 9.4%	2 7.4%	7 8.8%	0.762¥
	No	48 90.6%	25 92.6%	73 91.3%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.6 Association of Nasal Obstruction and anatomical variants

Nasal Obstruction	Agger Nasi Right		p-value	Agger Nasi Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	7 33.3%	14 66.7%	*0.014€	7 33.3%	14 66.7%	*0.014€
No (n=59)	38 64.4%	21 35.6%		38 64.4%	21 35.6%	
Total (n=80)	45 56.3%	35 43.8%		45 56.3%	35 43.8%	

Nasal Obstruction	Onodi Cells Right		p-value	Onodi Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	0 0.0%	21 100.0%	0.075¥	0 0.0%	21 100.0%	0.098¥
No (n=59)	8 13.6%	51 86.4%		7 11.9%	52 88.1%	
Total (n=80)	8 10.0%	72 90.0%		7 8.8%	73 91.3%	

Nasal Obstruction	Concha Bullosa Right		p-value	Concha Bullosa Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	6 28.6%	15 71.4%	0.868€	10 47.6%	11 52.4%	0.265€
No (n=59)	18 30.5%	41 69.5%		20 33.9%	39 66.1%	
Total (n=80)	24 30.0%	56 70.0%		30 37.5%	50 62.5%	

Nasal Obstruction	Haller Cells Right		p-value	Haller Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	3 14.3%	18 85.7%	0.608¥	2 9.5%	19 90.5%	0.884¥
No (n=59)	6 10.2%	53 89.8%		5 8.5%	54 91.5%	
Total (n=80)	9 11.3%	71 88.8%		7 8.8%	73 91.3%	

Nasal Obstruction	DNS Right		p-value	DNS Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	8 38.1%	13 61.9%	0.072€	6 28.6%	15 71.4%	0.898€
No (n=59)	11 18.6%	48 81.4%		16 27.1%	43 72.9%	
Total (n=80)	19 23.8%	61 76.3%		22 27.5%	58 72.5%	

Nasal Obstruction	DNS with Spur Right		p-value	DNS with Spur Left		p-value
	Yes	No		Yes	No	
Yes (n=21)	5 23.8%	16 76.2%	0.738€	6 28.6%	15 71.4%	0.34€
No (n=59)	12 20.3%	47 79.7%		11 18.6%	48 81.4%	
Total (n=80)	17 21.3%	63 78.8%		17 21.3%	63 78.8%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied, *p-value ≤0.05 considered to be statistically significant

Table 4.7 Association of Nasal Obstruction and anatomical variants (unilateral variant)

Unilateral Findings			
Nasal Obstruction	**Posterior Nasal Septal Air Cells**		**p-value**
	Yes	**No**	
Yes (n=21)	2 9.5%	19 90.5%	0.682¥
No (n=59)	4 6.8%	55 93.2%	
Total (n=80)	6 7.5%	74 92.5%	
Nasal Obstruction	**Aerated Crista Galli**		**p-value**
	Yes	**No**	
Yes (n=21)	1 4.8%	20 95.2%	0.439¥
No (n=59)	1 1.7%	58 98.3%	
Total (n=80)	2 2.5%	78 97.5%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

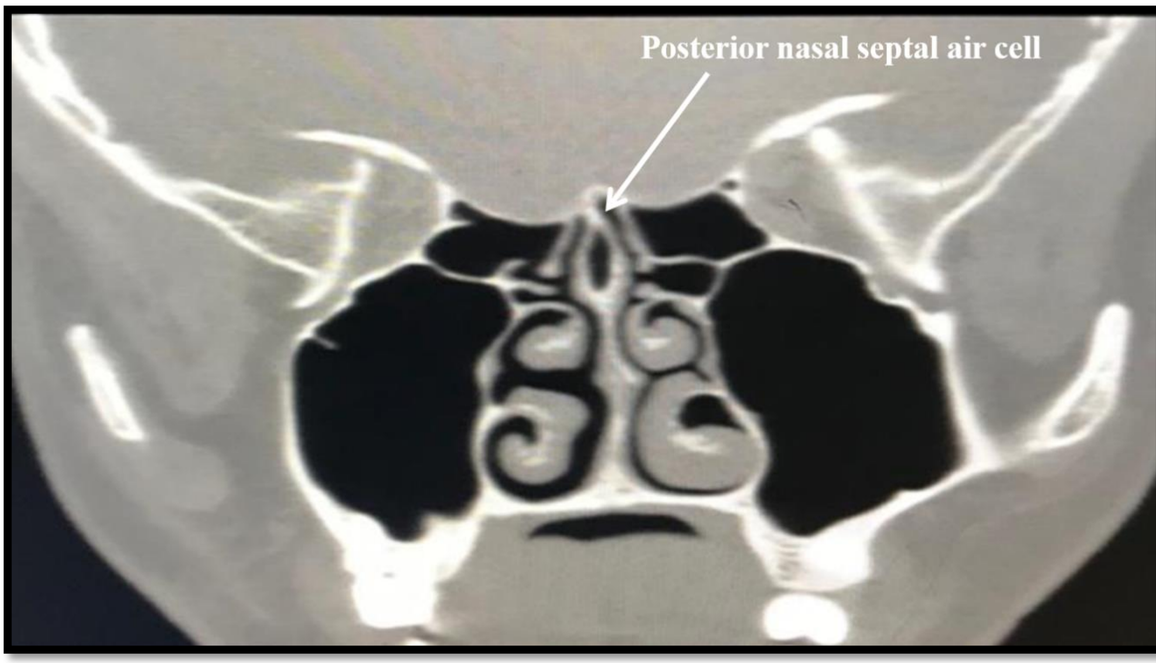


Figure 4.7 Coronal view of CT-PNS showing posterior nasal septal air cell in symptomatic patient of sinusitis (a rare anatomical variant of sinonasal region)

Table 4.8 Association of Headache and anatomical variants

Headache	Agger Nasi Right		p-value	Agger Nasi Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	17 43.6%	22 56.4%	*0.026[€]	17 43.6%	22 56.4%	*0.026[€]
No (n=41)	28 68.3%	13 31.7%		28 68.3%	13 31.7%	
Total (n=80)	45 56.3%	35 43.8%		45 56.3%	35 43.8%	

Headache	Onodi Cells Right		p-value	Onodi Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	4 10.3%	35 89.7%	0.941[¥]	3 7.7%	36 92.3%	0.744[¥]
No (n=41)	4 9.8%	37 90.2%		4 9.8%	37 90.2%	
Total (n=80)	8 10.0%	72 90.0%		7 8.8%	73 91.3%	

Headache	Concha Bullosa Right		p-value	Concha Bullosa Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	14 35.9%	25 64.1%	0.262[€]	15 38.5%	24 61.5%	0.862[€]
No (n=41)	10 24.4%	31 75.6%		15 36.6%	26 63.4%	
Total (n=80)	24 30.0%	56 70.0%		30 37.5%	50 62.5%	

Headache	Haller Cells Right		p-value	Haller Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	5 12.8%	34 87.2%	0.655€	5 12.8%	34 87.2%	0.209€
No (n=41)	4 9.8%	37 90.2%		2 4.9%	39 95.1%	
Total (n=80)	9 11.3%	71 88.8%		7 8.8%	73 91.3%	

Headache	DNS Right		p-value	DNS Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	9 23.1%	30 76.9%	0.89€	11 28.2%	28 71.8%	0.89€
No (n=41)	10 24.4%	31 75.6%		11 26.8%	30 73.2%	
Total (n=80)	19 23.8%	61 76.3%		22 27.5%	58 72.5%	

Headache	DNS with Spur Right		p-value	DNS with Spur Left		p-value
	Yes	No		Yes	No	
Yes (n=39)	8 20.5%	31 79.5%	0.875€	8 20.5%	31 79.5%	0.875€
No (n=41)	9 22.0%	32 78.0%		9 22.0%	32 78.0%	
Total (n=80)	17 21.3%	63 78.8%		17 21.3%	63 78.8%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied, *p-value ≤0.05 considered to be statistically significant

Table 4.9 Association of Headache and anatomical variants (unilateral variant)

Unilateral Findings			
Headache	**Post Nasal Septal Air Cells**		**p-value**
	Yes	**No**	
Yes (n=39)	2 5.1%	37 94.9%	0.432¥
No (n=41)	4 9.8%	37 90.2%	
Total (n=80)	6 7.5%	74 92.5%	
Headache	**Aerated Crista Galli**		**p-value**
	Yes	**No**	
Yes (n=39)	0 0.0%	39 100.0%	0.162¥
No (n=41)	2 4.9%	39 95.1%	
Total (n=80)	2 2.5%	78 97.5%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.10 Association of Facial Pain and anatomical variants

Facial Pain	Agger Nasi Right		p-value	Agger Nasi Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	1 20.0%	4 80.0%	0.091¥	1 20.0%	4 80.0%	0.091¥
No (n=75)	44 58.7%	31 41.3%		44 58.7%	31 41.3%	
Total (n=80)	45 56.3%	35 43.8%		45 56.3%	35 43.8%	

Facial Pain	Onodi Cells Right		p-value	Onodi Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	0 0.0%	5 100.0%	0.441¥	0 0.0%	5 100.0%	0.475¥
No (n=75)	8 10.7%	67 89.3%		7 9.3%	68 90.7%	
Total (n=80)	8 10.0%	72 90.0%		7 8.8%	73 91.3%	

Facial Pain	Concha Bullosa Right		p-value	Concha Bullosa Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	1 20.0%	4 80.0%	0.614¥	2 40.0%	3 60.0%	0.905¥
No (n=75)	23 30.7%	52 69.3%		28 37.3%	47 62.7%	
Total (n=80)	24 30.0%	56 70.0%		30 37.5%	50 62.5%	

Facial Pain	Haller Cells Right		p-value	Haller Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	1 20.0%	4 80.0%	0.522¥	1 20.0%	4 80.0%	0.358¥
No (n=75)	8 10.7%	67 89.3%		6 8.0%	69 92.0%	
Total (n=80)	9 11.3%	71 88.8%		7 8.8%	73 91.3%	

Facial Pain	DNS Right		p-value	DNS Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	2 40.0%	3 60.0%	0.378¥	0 0.0%	5 100.0%	0.155¥
No (n=75)	17 22.7%	58 77.3%		22 29.3%	53 70.7%	
Total (n=80)	19 23.8%	61 76.3%		22 27.5%	58 72.5%	

Facial Pain	DNS with Spur Right		p-value	DNS with Spur Left		p-value
	Yes	No		Yes	No	
Yes (n=5)	1 20.0%	4 80.0%	0.944¥	0 0.0%	5 100.0%	0.23¥
No (n=75)	16 21.3%	59 78.7%		17 22.7%	58 77.3%	
Total (n=80)	17 21.3%	63 78.8%		17 21.3%	63 78.8%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.11 Association of Facial Pain and some anatomical variants (unilateral variant)

Unilateral Findings			
Facial Pain	**Post Nasal Septal Air Cells**		**p-value**
	Yes	**No**	
Yes (n=5)	0 0.0%	5 100.0%	$0.511^{¥}$
No (n=75)	6 8.0%	69 92.0%	
Total (n=80)	6 7.5%	74 92.5%	
Facial Pain	**Aerated Crista Galli**		**p-value**
	Yes	**No**	
Yes (n=5)	0 0.0%	5 100.0%	$0.712^{¥}$
No (n=75)	2 2.7%	73 97.3%	
Total (n=80)	2 2.5%	78 97.5%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.12 Association of Rhinorrhea and anatomical variants

Rhinorrhea	Agger Nasi Right		p-value	Agger Nasi Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	9 20.0%	6 17.1%	0.782€	9 20.0%	6 17.1%	0.782€
No (n=65)	36 80.0%	29 82.9%		36 80.0%	29 82.9%	
Total (n=80)	45 100.0%	35 100.0%		45 100.0%	35 100.0%	

Rhinorrhea	Onodi Cells Right		p-value	Onodi Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	1 12.5%	14 19.4%	0.534¥	1 14.3%	14 19.2%	0.609¥
No (n=65)	7 87.5%	58 80.6%		6 85.7%	59 80.8%	
Total (n=80)	8 100.0%	72 100.0%		7 100.0%	73 100.0%	

Rhinorrhea	Concha Bullosa Right		p-value	Concha Bullosa Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	2 8.3%	13 23.2%	0.21¥	6 20.0%	9 18.0%	0.824¥
No (n=65)	22 91.7%	43 76.8%		24 80.0%	41 82.0%	
Total (n=80)	24 100.0%	56 100.0%		30 100.0%	50 100.0%	

Rhinorrhea	Haller Cells Right		p-value	Haller Cells Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	1 11.1%	14 19.7%	0.685¥	2 28.6%	13 17.8%	0.610¥
No (n=65)	8 88.9%	57 80.3%		5 71.4%	60 82.2%	
Total (n=80)	9 100.0%	71 100.0%		7 100.0%	73 100.0%	

Rhinorrhea	DNS Right		p-value	DNS Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	4 21.1%	11 18.0%	0.764¥	2 9.1%	13 22.4%	0.215¥
No (n=65)	15 78.9%	50 82.0%		20 90.9%	45 77.6%	
Total (n=80)	19 100.0%	61 100.0%		22 100.0%	58 100.0%	

Rhinorrhea	DNS with Spur Right		p-value	DNS with Spur Left		p-value
	Yes	No		Yes	No	
Yes (n=15)	2 11.8%	13 20.6%	0.506¥	2 11.8%	13 20.6%	0.506¥
No (n=65)	15 88.2%	50 79.4%		15 88.2%	50 79.4%	
Total (n=80)	17 100.0%	63 100.0%		17 100.0%	63 100.0%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

Table 4.13 Association of Rhinorrhea and anatomical variants (unilateral variant)

Unilateral Findings			
Rhinorrhea	**Post Nasal Septal Air Cells**		**p-value**
	Yes	**No**	
Yes (n=15)	0 0.0%	15 20.3%	0.588¥
No (n=65)	6 100.0%	59 79.7%	
Total (n=80)	6 100.0%	74 100.0%	
Rhinorrhea	**Aerated Crista Galli**		**p-value**
	Yes	**No**	
Yes (n=15)	0 0.0%	15 19.2%	0.359¥
No (n=65)	2 100.0%	63 80.8%	
Total (n=80)	2 100.0%	78 100.0%	

€ Chi-square Test applied, ¥ Fischer Exact Test applied

CHAPTER 5

DISCUSSION

Literature search shows that, some of the areas in PNS are at great risk for injuries with consequential intra-operative complications. Hence the knowledge of anatomical variations of PNS is crucial for endoscopic surgeons as well as for radiologists for preoperative evaluation and in order to avoid iatrogenic complications (Piskunov & Emel'ianova, 2011).

The computed tomography (CT) is considered as the gold standard radiological investigation for the assessment of nasal cavity and paranasal sinuses (PNS) diseases. There are many anatomic variants in sinonasal region which can be easily detected by CT scan (Bâldea, Indrei, Ciupilan, & Scutariu, 2010; Piskunov & Emel'ianova, 2011; Robinson, Donlon, Harrison, Houang, Stammberger & Wolf, 2010).

The nose and Paranasal sinuses (PNS) also called sinonasal region collectively form a single anatomical and functional unit. Various normal anatomical variations are observed in this region. Conventional X-rays do not offer adequate information. There has been advancement in the surgical management of sinusitis in recent years, particularly in Endonasal Functional Endoscopic Sinus Surgery (FESS), which requires the radiologist to identify the various anatomical variations of nasal cavity and PNS in order to make aware the clinician to have detail knowledge of sinonasal anatomy and anatomical variants, many of these anatomical variations are detectable only by the use of computed tomography (CT) (Lingaiah et al., 2016).

Sinonasal pathologies are one of most common health problems which are frequently observed in clinical rhinologic practice. Even though sinus mucosal inflammation termed as sinusitis is a clinical diagnosis, but at the same time various imaging studies are used to assess the disease and demonstrate the complex sinonasal anatomy and anatomical variations including sinus mucosal diseases. Currently, computed tomography (CT) especially on coronal plane is the most common method used by many surgeons because of its similarity with the surgical orientation. The effects of anatomical variations on sinus diseases have been investigated widely. Despite the presence of many reported studies that focused on whether these anatomical variations play a role in the etiology of sinusitis, any consensus seems to be remote (Kaygusuz et al., 2014; Qureshi & Usmani, 2020).

The present study was conducted to determine the incidence of sinonasal anatomic variants in symptomatic subjects of sinusitis on CT-scan and to assess association between gender, anatomic variants of sinonasal region and symptoms of sinusitis which includes headache, nasal obstruction, rhinorrhea and facial pain.

The anatomy of nasal cavity and paranasal sinuses (PNS) is difficult to understand because of its complicity. To evaluate the sinonasal anatomy, anatomical variations, disease pathology and to diagnose the diseases at this area, physical examination and conventional radiographic examinations are not always able to provide sufficient information. Computed tomography (CT) provides valuable information preoperatively in order to prevent harmful hazards of the surgery. The advantage of this approach for endoscopic sinus surgery is that; it can provide anatomical and pathological image with the same perspective to the surgeon. Sinonasal region that possess frequently anatomic variations, plays an important role in the pathogenesis of paranasal sinus diseases (Dalgorf & Harvey, 2013; Kaygusuz et al., 2014).

The present study included symptomatic subjects of sinusitis and findings of CT scan of the paranasal sinuses were studied. In all cases, following anatomical variants were investigated:

Nasal septum: septal deviation, septal bony spur, turbinate: superior concha bullosa, middle concha bullosa, paradoxical (false) middle concha, hypoplasia, and secondary middle concha, uncinate process: deviation of the upper edge, pneumatization, ethmoid air cells: agger nasi cells, haller cells, ethmoid bulla, onodi cells, other variants included: hypoplasia of the maxillary sinus, maxillary septa, hypoplastic frontal sinus and asymmetry of both cavities of the sphenoid sinus (septate sphenoid sinus). And some rare anatomical variants of the paranasal region such as aerated crista galli and posterior nasal septal air cell were also investigated.

Numerous authors have evaluated and assessed the relationship between anatomical variations of sinonasal region and the incidence of sinusitis (Danese et al., 1997; Ercan et al., 2006; Kaygusuz et al., 2014; Selcuk et al., 2008). This is a topic of interest for every surgeon who is dealing with nasal cavity and sinuses to understand the radiological definition of paranasal regional normal anatomy, variations including sinus pathologies (Zinreich et al., 1987). Some anatomical variations which are directly related with the lateral wall of nasal cavity are very important because these variants can contribute to the obstruction and blockage of the osteomeatal complex (OMC), can impair sinus drainage, sinus ventilation and thereby these factors can increase the risk of sinus mucosal disease (Bayram, Sirikci & Bayazıt, 2001). Furthermore, there are many anatomical variants which possess crucial clinical as well as surgical importance and especially those anatomic variants with a potential impact on surgical safety need to be specifically sought as a significant part of preoperative evaluation (Stammberger & Posawetz, 1990).

Proper PNS radiological imaging and accurate interpretation play an important role in the diagnosis and management of various sinonasal pathologies. CT-PNS plays a key role in the modern endoscopic management of sinus mucosal conditions due to its ability to describe normal sinus anatomy, anatomical variations, mucosal disease, to demonstrate a primary obstructive pathology and to image various distal structures for instance the posterior ethmoid sinus that cannot be viewed with direct endoscopic examination (Earwaker, 1993).

Bolger et al., in 1991 reported that anatomical variations of sinonasal region may cause recurrent sinus infections and, in some cases, patient may present with complain of headache. In 2017 Venkateswaran, Muthukumar & Anandan, observed most common symptom nasal obstruction with reported frequency of 88% followed by headache 80%. However, in the current study of 80 subjects, there were 53 (66.3%) males and 27 (33.8%) females and the most common symptom observed in symptomatic subjects of sinusitis was headache with frequency of 48.75% (in 26 males and 13 females) followed by nasal obstruction with frequency of 26.25% (in 16 males and 5 females), rhinorrhea with frequency of 18.75% (in 9 males and 6 females), and facial pain with frequency of 6.25% (in 2 males and 3 females). Sahu et al., 2017 contradicts with the present study as nasal obstruction was found to be the most common symptom with reported frequency of 96 (86.7%) followed by rhinnorrhea in 84 (79.2%) cases whereas headache was observed in 74 (69.81%) and in addition to this Rathor and Bhattacharjee, 2017, Savović et al., 2019 also showed contradictory results as compared to the present study. Though, the relative importance of anatomical variants of sinonasal region is still a matter of detailed discussion, variable results have been reported (Nair, 2009).

The anatomy of the sinonasal region has a wide range of anatomical variations, some of which are shown in the present study. In 2016 a study reported that 77.7% anatomical variations of sinonasal region were observed in patients of sinusitis (Murthy, Rao & Rao, 2016). In 1999, Liu et al. observed similar findings and reported prevalence of 81% anatomical variations in cases of sinusitis. In 2006, de Araújo Neto et al. revealed less anatomical variations in the subjects of sinusitis with reported frequency of 65%. Perez-Pinas, Sabate, Carmona, Catalina-Herrera, & Jimenez-Castellanos, (2000) observed similar prevalence of anatomical variants in subjects of sinusitis. In 2019 out of 100 participants anatomical variations of nasal cavity and PNS were observed in 95 subjects having sinus mucosal infection (Devareddy & Devakar, 2019). The present study of 80 subjects found prevalence of 100% presence of various anatomical variations of nasal cavity and paranasal sinuses along with mucosal thickening of sinuses in symptomatic subjects of sinusitis.

When midline nasal septum is deviated or deflected significantly off-center or twisted from midline is termed as deviated nasal septum (DNS) (Khan et al., 2020). It depends on the degree of nasal septum midline shift that how much anatomy of nasal cavity is distorted and turbinates are displaced which obstruct nasal airflow and sinus drainage. The presence of bony spur can worsen the obstructive symptoms (de Miranda et al., 2011; O'Brien Sr, Hamelin, & Weitzel, 2016). DNS is a common anatomical variant of sinonasal region which is present in 20-79% of people (Vaid & Vaid, 2015). Talaiepour et al., in 2005 reported that deviated nasal septum was found as most common anatomical variation in patients of sinusitis with reported frequency of 63% out of which 28% deviated to the right and 31.5% to the left side; bilateral deviation was seen in 3.5%.

Mathuram et al., 2019 stated that among all the anatomical variations of PNS, DNS is the most common variant, found in 71% of cases. Most of the recent studies conducted by

Adeel et al., (2013), Aramani, Karadi & Kumar, (2014), Suri et al., (2016), and Shiekh, Wani, Khan & Bhat, (2019) had also disclosed that DNS as most common anatomical variant of sinonasal region accounting for 26%, 74.1%, 75% and 85% respectively.

In 2016 Gupta, Gurjar & Mishra, observed similar findings and reported DNS in 78.8% followed by paradoxical middle turbinate (46.10%). Devareddy et al., (2019) revealed that 62% of subjects exhibited DNS and also showed slight predominance to the left side (28%) as compared to right side (26%). The present study found similar results as DNS was observed in 47 subjects (32 males and 15 females) with frequency of 58.8%. In addition to this, presence of bony spur was observed in 32 subjects (23 males and 9 females) with frequency of 40%. In contrast to Gupta et al., (2016) second most common anatomical variant was observed agger nasi cells in 45 patients with reported frequency of 56.3% whereas paradoxical middle concha was found in 1 patient with frequency of 1.3%.

After DNS, the most common variant observed in the literature was agger nasi cells which were ethmoturbinal remnant and lie deep to lacrimal bone and these cells borders the ostium or the floor of frontal sinus, their size may directly influence the patency of the frontal recess and the anterior nasal middle meatus (Al-Qudah, 2010). The anterior most ethmoidal cells are called as agger nasi cells and their prevalence is noticed in more than 90% of the patients (Shpilberg et al., 2015; Yousem & Grossman, 2010). These cells lie on the upper margin of the nasolacrimal duct and form inferior margin of frontal recess. And because of these crucial relationships, a giant agger nasi cells can be a cause of frontal sinusitis or excessive epiphora. The agger nasi cells are important surgical reference as well (Kantarci et al., 2004). In 2010, Al-Qudah revealed that out of 110 subjects, 92 subjects had agger nasi cells with reported frequency of 80%, followed by second most common anatomical variant concha bullosa (CB) in 62% of the subjects which contradicts with the present study as agger nasi cells were second most common anatomical variant found in symptomatic subjects of sinusitis. A study revealed almost similar results, that all 110 cases were having these most anterior ethmoidal cells namely agger nasi cells (Perez-Pinas et al., 2000). Peter (2003) considered this particular cell as the crucial key for understanding the complex anatomical arrangement of the frontal recess. Since these cells have close relationship to the orbit and lacrimal sac, so any infection of agger nasi cell can cause ocular pathology and various visual symptoms (Peter, 2003). In the literature it is reported that, the prevalence of agger nasi cells varies from 10% to 98.5% (Lingaiah et al., 2016). The prevalence reported in past few years includes Gouripur et al., (2017) found these cells in 96% subjects, Espinosa et al., (2018) reported incidence of agger nasi cells as 78.3%, Alshaikh & Aldhurais, in 2018 found 100% prevalence of agger nasi cells, Yazici, 2019 quoted its prevalence as 82% whereas Shrestha et al., (2019) found prevalence of 18.4% of agger nasi cells. The current study supports the literature findings as it was noticed that the presence of agger nasi cells was found bilaterally in 45 subjects suffering from sinusitis with frequency of 56.3% as second most common anatomical variant found in symptomatic subjects of sinusitis.

Out of other anatomical variants of sinonasal region middle CB was observed in 37 (46.3%) cases where as superior and paradoxical middle turbinate was observed in 1 subject with frequency of (1.3%). Uncinate process deviation and pneumatization was observed in 2.5% and 3.8% of the patients respectively. Out of other ethmoid cells, haller cells and onodi cells were observed in 11.3% and 12.5% of the symptomatic subjects of sinusitis. Remaining other variants which were found include maxillary septa in 1.3%, hypoplastic frontal sinus in 31.3% and asymmetry of both cavities of the sphenoid sinus was observed in 18.8% of the cases.

In present study, out of 80 symptomatic patients of sinusitis there were 53 (66.3%) male and 27 (33.8%) female. So, the sinonasal symptoms were observed more in males as compared to females. The association between gender and symptoms in subjects with sinusitis were non-significant. The association between gender and anatomical variations of sinonasal region in symptomatic subjects of sinusitis were non-significant.

Savović et al., (2019) supported the findings of current study that out of 90 patients 51 were men (56.7%) and 39 were women (43.3%) with sinonasal symptoms. Handi and Patil (2017) support the present study and reported that out of 51 subjects there were more male subjects (34-66.7%) than female subjects (17-33.3%) suffering from sinonasal symptoms which is consistent with literature reported by Amodu, Fasunla, Akano & Olusesi, (2014), Fadda, Rosso, Aversa, Petrelli, Ondolo & Succo, (2012), Kushwah, Bhalse, & Pande, (2015), Lupoi & Sarafoleanu, (2012), Nikakhlagh, Bakhshi, & Noroozi, (2015), Rathor et al., (2017), whereas Tiwari & Kardam, (2019) contradicts and reported slight female preponderance as out of 142 patients 69 were males and 73 were females and also Sumaily et al., (2018) contradicts and stated that no significant gender variation was observed instead more females cases were reported in the study (49.8% males and 50.2% females). In addition to this, author revealed that in the literature, there is no data regarding the gender relation to these anatomical variations in detail so with this regard present study reports about the various correlations between gender, symptoms of sinusitis and various anatomical variations of paranasal sinuses.

Along with anatomical variations involved; sinuses in sinusitis were also investigated in the present study and the most common sinus observed was maxillary sinus followed by ethmoid, sphenoid and frontal sinus. Their mucosal thickening was considered. In this regard correlation between gender and involvement of sinuses were also observed and statistically no association was found between gender and any of the involved sinus in symptomatic subjects of sinusitis who had various anatomical variations of nasal cavity and paranasal sinuses (Table 4.5). This finding was supported by Handi and Patil (2017), Kanwar et al., (2017), Kushwah et al., (2015), Rathor et al., (2017), and Verma, Tyagi, Srivastava & Agarwal, (2016).

Almost each anatomical variant of paranasal sinus is of surgical importance. In present study the association of sinusitis symptoms (nasal obstruction, headache, facial pain and rhinorrhea) and some anatomical variants of PNS including right and left sided variants agger nasi cells, onodi cells, CB, haller cells, DNS, DNS with spur, and unilateral variants which includes aerated crista galli and posterior nasal septal air cells were compared. The symptom nasal obstruction was observed in 21 patients out of 80 patients and when its association was compared with various anatomical variants it was noticed that nasal obstruction was seen in those patients who were having agger nasi cells on both sides with significant p-value of 0.014. Non-significant association was observed between other anatomical variants of sinonasal region and nasal obstruction.

When headache was compared with various anatomical variations of sinonasal region, it was noticed that headache was associated with agger nasi cells on both sides with significant p-value of 0.026. Non-significant association was observed between other anatomical variants and headache. Moreover, non-significant association was observed between anatomical variants of sinonasal region and other symptoms i.e. facial pain and rhinorrhea.

CHAPTER 6

CONCLUSION

6.1 Conclusion of study

On the basis of this study, it can be concluded that headache is the most frequent symptom out of nasal obstruction, facial pain and rhinorrhea in symptomatic subjects of the sinusitis. There are anatomical variations of nasal cavity and paranasal sinus region in Pakistani population and these anatomical variations were prevalent as 100% in symptomatic subjects of sinusitis with significant number found in male gender.

The most frequent anatomical variant found in symptomatic patients of sinusitis was deviated nasal septum (DNS) followed by agger nasi cells, concha bullosa (CB), septal bony spur, hypoplastic frontal sinus, asymmetry of both cavities of the sphenoid sinus, onodi cells, haller cells, uncinate process deviation and pneumatization, superior CB, paradoxical middle CB, and maxillary septa. Furthermore, nasal obstruction and headache was compared with various anatomical variations of sinonasal region it was noticed that nasal obstruction and headache were significantly associated with agger nasi cells on both right and left sides. The association between gender, involved sinuses, anatomical variants and symptoms in patients with sinusitis was insignificant.

6.2 Recommendations

In this era, precise knowledge of the complex anatomy along with variations of PNS is essential for the surgeon. CT-PNS scan provides accurate identification of the normal morphology, anatomical variants and the extent of the disease in and around the nasal cavity and paranasal sinus region.

There are various anatomical variations of nasal cavity and paranasal sinuses, and out of those variations some were considered in this study, with this regard remaining anatomical variations such as variation of optic nerve in relation to sphenoid sinus, Keros classification and etc. can be a new topic for more studies. Further endoscopic examinations of various anatomical variations can be compared with CT scan findings. A case control study between symptomatic and non-symptomatic patients of sinusitis can be a new idea for upcoming years. Moreover, consideration of mucosal contact points and Lund Mackay scoring are also recommended for future studies. Along with this infected with sinusitis and non-infected subjects can be looked for these various anatomical variations in order to correlate the significant ratio of these anatomical variations in Pakistani population for further better prediction of treatment strategies.

6.3 Strengths of study

This study is highlighting the importance of CT scan evaluation of various anatomical variations of nasal cavity and paranasal sinuses in symptomatic subjects of sinusitis. In addition to this no data is present in the literature regarding association of these various anatomical variation with regard to gender and symptoms of sinusitis. This study gives a clue that sinusitis is more prevalent in male gender. In addition to this, anatomical variants are more frequent in male as well. The study yielded that every patient of sinusitis had anatomical variation which means anatomical variations of nasal cavity and paranasal sinuses are quite common and their surgical importance should not be over looked for various surgical procedures such as FESS or other skull base surgeries.

6.4 Limitations of study

Larger population size and multicenter options must be taken in order to authenticate study further. All anatomical variants of sinonasal region reported in the literature are not included in this study. The present study did not look for association between any of the anatomic variants of sinonasal region and severity of the disease/mucosal contact points due to restricted time period for study completion.

CHAPTER 7

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CHAPTER 8

APPENDICES

(A) BUMDC- FRC Approval letter

FACULTY RESEARCH COMMITTEE
BAHRIA UNIVERSITY MEDICAL & DENTAL COLLEGE

Ref No: FRC-BUMDC -13/ 2019/Ana-001

Date: 9th October, 2019

To,
Dr. Maryam Faiz
M.Phil. Student
Department of Anatomy
BUMDC, Karachi

Subject: **APPROVAL OF SYNOPSIS**

The Faculty Research Committee has approved the synopsis of below mentioned Student.

Name of Student: Dr. Maryam Faiz

Title: **Anatomical Variations of Nasal cavity and Paranasal Sinuses in Acute Sinusitis on CT scan.**

Further this letter is recommended and referred to ERC for approval on ethical grounds.

Regards
Assist Prof. Dr. Mehreen Lateef,
CO- CHAIRPERSON FRC-BUMDC

Cc:
Director General
Principal
FRC Record
PG Secretariat

Faculty Research Committee, Bahria University Medical College
Sailor's Street, Adjacent PNS-SHIFA DHA
Webmail: rrc-bumdc@bahria.edu.pk

(B) BUMDC –ERC Approval letter

BAHRIA UNIVERSITY MEDICAL AND DENTAL COLLEGE

Defence phase II, Sailor Street, adjacent to PNS Shifa, Karachi. Tel: 021-35319491-9

ETHICAL REVIEW COMMITTEE

LETTER OF APPROVAL

Date: 09-Jan-2020

PATRON
Prof. Asad Ullah Khan
Principal & Dean Health Sciences(BU)

CHAIRPERSON
Dr. Quratul Ain Omaeer

SECRETARY (Adhoc)
Dr Ambreen Surti

MEMBERS
Prof M Alamgir
Prof Anis Jafarey
Ms Nighat Huda
Surg Cdre Amir Ejaz
Prof Reza H Syed
Ms Shabina Arif
Mr M Amir Sultan
Surg Lt Cdr Farah
Surg Lt Cdr Sadia

Dr. Maryam Faiz Qureshi
M. Phil Student
Department of Anatomy
BUMDC-Karachi

Subject: Institutional Approval of research study

Title of Study: "Anatomical Variation of nasal cavity and paranasal sunuses in acute sinusitis on CT-Scan"

Principal Investigator: Dr. Maryam Faiz Qureshi, M. Phil Student Department of Anatomy, Bahria University Medical and Dental College.

Reference No: ERC 05/2020

Dear Dr. Maryam Faiz Qureshi

Thank you for submitting the above mentioned study proposal. ERC Bahria University Medical and Dental College has reviewed this project in the meeting held on 2nd - Jan -2020 and gives approval. Kindly notify us when the research is complete.

Regards,

10/1/2020

DR. AMBREEN SURTI
Secretary
BUMDC

10/1/2020

DR. QURATUL AIN OMAEER
Chairperson
BUMDC

Cc:
DG-BUMDC
Principal BUMDC
Chairperson ERC

(C) Consent Form (English)

WRITTEN INFORMED CONSENT FORM OF PATIENT

I am giving my consent to participate voluntarily and at my own will in the research project that aims for identification and early detection of anatomical variations of paranasal sinuses (PNS). The project will evaluate anatomical variations of PNS for early detection and prevention of surgical hazards of functional endoscopic sinus surgery (FESS).

I have been explained in detail the nature and significance of participating in the project and I understand the provided explanation.

I have been told that findings of my disease and my data will be kept strictly confidential and will be used only for the benefit of community, publications and paper presentations.

I have been explained that radiological investigation CT scan will be conducted to evaluate my health status and to diagnose and monitor my disease process along with evaluation of anatomical variations of paranasal sinuses. For this purpose, I fully agree to participate in this study by giving my CT scan reports.

I also agree to give all relevant information needed, in full and to the best of my knowledge to the researcher. It is clarified to me that no incentive, financial assistance or reimbursement will be provided to me for participating in the study whereas I do have the right to withdraw from the study at any time.

I am advised to contact Dr. Maryam Faiz Qureshi on mobile number 03352844333 or visit PNS Shifa hospital in case of query/ emergency related to my disease.

Name of Patient: ______________________

S/o, D/o, W/ o__________________

Signature of Patient: _________________

Name of Researcher: Dr Maryam Faiz Qureshi

Signature of Researcher: ______________

Date: _____________

(D) Consent Form (Urdu)

آ گاہی شدہ رضا کارانہ فارم برائے مریض

میں رضا کارانہ طور پر اور اپنی پوری مرضی کے ساتھ اس تحقیق میں حصہ لے رہا ہوں / لے رہی ہوں جس کا مقصد پیرانیسل سانس (ناک کے گرد کے سانس PNS) میں بناوٹی متغیرات کا ابتداء میں پتا لگانا ہے۔

یہ تحقیق PNS کے بناوٹی متغیرات کو ابتداء میں ہی پکڑنے اور نلکی کے ذریعے آپریشن (FESS) میں ہونے والے مسائل کو کم کرنے میں مددگار ثابت ہوگی۔

مجھے تفصیل سے اس تحقیق میں حصہ لینے کی نوعیت اور اہمیت بتا دی گئی ہے اور میں فراہم کردہ وضاحت کو اچھے سے سمجھ گیا / سمجھ گئی ہوں۔

مجھے بتا دیا گیا ہے کہ میری بیماری کے نتائج اور اعداد و شمار کو خفیہ رکھا جائے گا اور صرف برادری، اشاعت اور مطالعہ کی پیشکش کیلئے استعمال کیا جائے گا۔

مجھے یہ بھی بتا دیا گیا ہے کہ اس کیلئے شعاعوں سے تحقیق (CT Scan) بھی کیا جائے گا جس سے میری صحت اور بیماری کی جانچ کی جائے گی، جس سے PNS کے بناوٹی متغیرات بھی پتا چلنے میں مدد ملے گی اس سلسلے میں میں اپنی (CT Scan) کی رپورٹ بھی دینے پر رضامند ہوں۔

میں اس بات سے بھی متفق ہوں کہ ضرورت کے تحت اپنی معلومات فراہم کروں گا / کرونگی۔ یہ بات بھی میرے علم میں ہے کہ اس تحقیق میں حصہ لینے کیلئے مجھے کسی کا معاوضہ یا حوصلہ افزائی نہیں دی جائیگی جبکہ مجھے اپنی مرضی سے اس تحقیق سے نکلنے کا حق حاصل ہے۔

کسی بھی قسم کے سوال یا ہنگامی صورت حال میں مجھے ڈاکٹر مریم فیض قریشی سے ان کے موبائل نمبر ---------------- پر یا PNS Shifa اسپتال سے رابطہ کرنے کا مشورہ دیا گیا ہے۔

مریض کا نام: ____________________

والد / شوہر کا نام: ____________________

دستخط: ____________________

محقق کا نام: ____________________

دستخط: ____________________

تاریخ: ____________________

(E) Subject Evaluation Proforma / Questionnaire

QUESTIONNAIRE

Hospital Registration No: .... Case No: ………………..

DEMOGRAPHIC DATA

Name____

Age: _______________________

Gender: ___________________

Residential address: ____

Date of CT Scan: ____

Mobile No: ____

SYMPTOMS OF PATIENTS

- Nasal obstruction ☐
- Headache ☐
- Facial pain ☐
- Rhinorrhea ☐

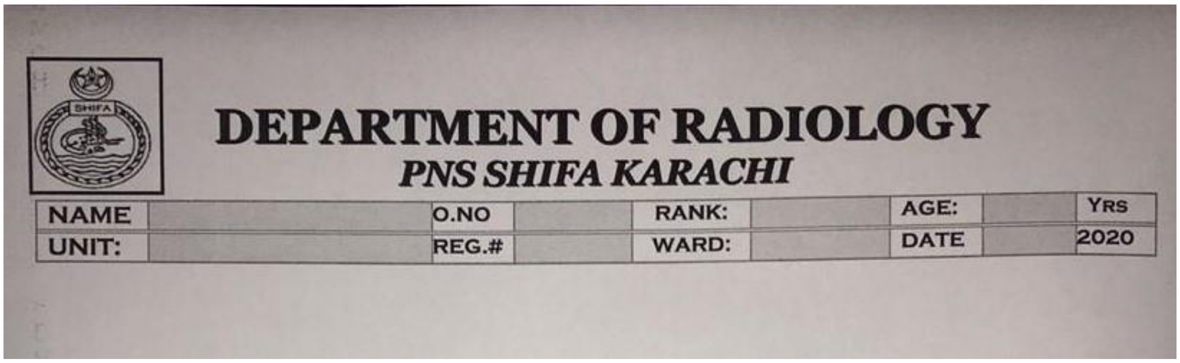
CT SCAN OF THE PARANASAL SINUSES FINDINGS

- CT Scan View
  - Coronal plane ☐
  - Axial View ☐
  - Both View ☐
- Nasal septum
  - Septal deviation ☐
  - Septal bony spur ☐
- Turbinates
  - Superior concha bullosa ☐
  - Middle concha bullosa ☐
  - Paradoxical (false) middle concha ☐
  - Hypoplasia ☐
  - Secondary middle concha ☐
- Uncinate process
  - Deviation of the upper edge ☐
  - Pneumatization ☐
- Ethmoid air cells
  - Agger nasi cells ☐

- ▪ Haller's cells ☐
- ▪ Great ethmoid bulla ☐
- ▪ Onodi cells (extramural sphenoid cells) ☐

- other variants
  - ▪ Hypoplasia of the maxillary sinus ☐
  - ▪ Maxillary septa ☐
  - ▪ Hypoplastic frontal sinus ☐
  - ▪ Asymmetry of both cavities of the sphenoid sinus ☐

(F) Hospital / Institute Card

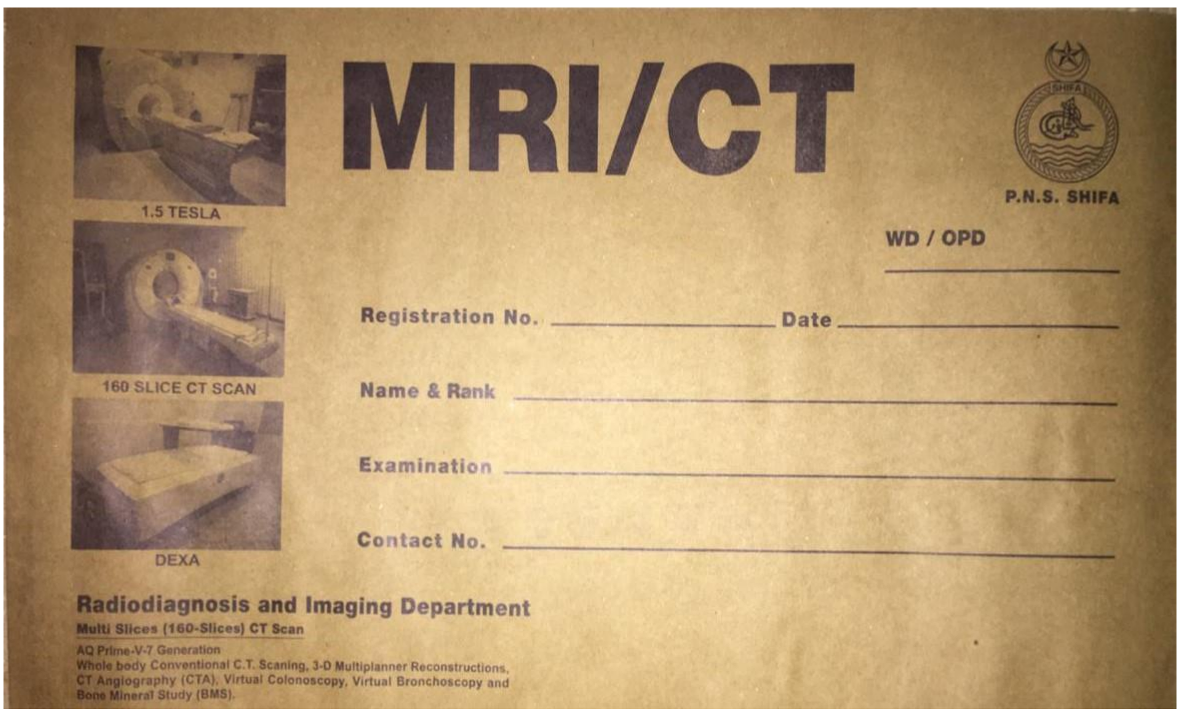


SHIFA

DEPARTMENT OF RADIOLOGY

PNS SHIFA KARACHI

NAME		O.NO		RANK:		AGE:		YRS	
UNIT:		REG.#		WARD:		DATE		2020	



MRI/CT

SHIFA

P.N.S. SHIFA

1.5 TESLA

160 SLICE CT SCAN

DEXA

WD / OPD ____________

Registration No. ____________ Date ____________

Name & Rank ____________

Examination ____________

Contact No. ____________

Radiodiagnosis and Imaging Department

Multi Slices (160-Slices) CT Scan

AQ Prime-V-7 Generation
Whole body Conventional C.T. Scaning, 3-D Multiplanner Reconstructions,
CT Angiography (CTA), Virtual Colonoscopy, Virtual Bronchoscopy and
Bone Mineral Study (BMS).

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