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Research Article

Anatomical study of variant paranasal sinuses in accordance with its clinical significance by CT scan: Pre-COVID-19 period

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Diseases of para nasal sinuses and rhino sinusitis are fairly common condition affecting 21 to 40 age group i.e. 63.5% of total population in the present study. Computed tomography is of gold standard method and has fundamental role in Radiological investigation of para nasal sinuses either for diagnosis of sinonasal lesion or pre and post-surgical assessment. It is having capability in delineating the anatomical variants in paranasal sinuses so as to protect essential structures around paranasal sinuses from any hydrogenic injuries and preventing the recurrent diseases from extramural cells. It is of Paramount importance that computed tomography of paranasal sinuses in three dimensions of axial coronal and sagittal plane has to be acquired and adequately reviewed prior to functional endoscopic sinus surgery or other skull base surgeries. Awareness of possibility of such variation helps in making therapeutic decisions. The knowledge regarding the presence of extended pneumatization of frontal sinus into crista-galli, sphenoid sinus into greater wing and clinoid are important in skull base and orbital apex surgeries where delicate neural tissues and nerves are at risk of iatrogenic injuries. Similarly dehiscence of vidian nerve, infraorbital nerve predispose above structures to injury while sinus clearance in functional endoscopic sinus surgery. So keeping in mind of all related complication and aiming for proper precaution, the knowledge of Anatomy of the paranasal Sinuses are essential in this era of functional endoscopic sinus surgeries. The present study will help to understand the clinical significance of Anatomical variation of paranasal sinuses and also helpful to locate the normal anatomy of paranasal sinuses on computed tomography. This study is prospective observational study and conducted in the Department of Anatomy and Radio diagnosis, Government Medical College and Hospital, Aurangabad. The study was performed on randomly selected 200 human adult male and female patients admitted in the hospital with proper applicable inclusion and exclusion criteria. The findings of the present study was compared with those of previous studies and found important in aspects of skilled paranasal surgeries and for paramount diagnosis.

Key words: Anatomy, variations, paranasal sinuses, embryology

INTRODUCTION

Paranasal sinuses are air containing hollow spaces in the skull around the nasal cavity. They are lined by mucous membrane of ciliated columnar epithelium. They develop as mucous diverticula of nasal cavity and invade the neighbouring bones at the expense of the diploic tissue. The sinuses are arranged in pairs and are named after the bones that contains them i.e. Maxillary (cheekbone), Ethmoid (beside the upper nose), Frontal (lower forehead) and Sphenoidal (behind the nose) sinuses. All sinuses are present in rudimentary form at birth, except the frontal sinuses which start development two or three years after birth. On an average, the sinuses exhibit two spurs of growth, at about 7/8 years of age during the dentition of permanent teeth and in post-pubertal life. Apart from making skull light weight and improve voice quality, the sinuses have main function to produce mucus that moisturises the inside of nose which in turn protects the nose from pollutants, micro-organism, dust and dirt. The precise knowledge of paranasal sinuses is essential for surgeons while performing functional

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endoscopic sinus surgery because paranasal sinus diseases are common and on occasion becomes life threatening if not treated in time. As well as accurate depiction of normal and variant Anatomy and extent of Pathology of sinuses is needed to ovoid intra operative complications. Computed tomography is a fast and readily accessible imaging technique. The examination is well tolerated and therefore suited to very elderly or infirm patients as well as children, people with claustrophobia, or patients who are critically ill.

A CT scan shows the anatomical variations and the extent of the disease and is essential if surgical treatment is to be implemented. It is not considered as the primary step in the diagnosis of the condition, except where there are unilateral signs and symptoms or other sinister features, but rather corroborates history and endoscopic findings after failure of medical therapy. Also intravenous contrast medium injection is not required in the procedure unless a tumour, vascular lesion, or acute complication is suspected. Computed tomography provides detailed pictures of Anatomy, Anatomical variants and extent of disease in and around paranasal sinuses. Also by the method of axial sections, coronal scanning and sagittal reconstruction, accurate delineation of micro anatomic nlocales and disease in paranasal sinuses can be assessed (Perez-Pinas I, et al. 2000). Knowledge of anatomic variations reduces surgical complications during FESS (Functional endoscopic sinus surgery), so while identifying anatomic variation, all views i.e. coronal, sagittal and axial are recommended to assess different anatomical structures of lateral nasal wall and paranasal sinuses.

The role of pre-operative CT scan is useful in checking the anatomic variations of paranasal sinuses and variation has to be kept in mind during FESS to prevent complications; and has be treated simultaneously during surgery for adequate improvement following surgery and to prevent recurrence. In this way CT scan provides a guide map for FESS surgeons to operate and is useful in post-operative follow up (Bolger WE, et al. 1991). The paranasal sinus cancer can be cured if detected early and it becomes possible if the surgeon aware of common, unavoidable variations of these sinuses.

AIMS AND OBJECTIVES

1. To study normal Anatomy and Anatomical variation of paranasal sinuses by computed tomography

2. To support the Radiologist, Clinician with current study variation data for diagnosis, treatment or intervention of paranasal sinus pathologie

3. To understand and compare clinical significance of Anatomical variation of paranasal sinus with those of similar studies

4. To formulate and utilise the current study data to analyse its importance in COVID positive patients

Anatomy of paranasal sinus

There are 4 paranasal sinuses around the nasal cavity (Gray H et al. 1998). They are,

Maxillary sinus: This is pyramidal in shape with an apex in the zygomatic process of maxilla bone and base at the lateral wall of the nose. Infratemporal fossa and pterygopalatine fossa lies behind the posterior wall of maxillary sinus. Roof of the sinus is formed by the floor of orbit. The floor of the sinus is formed by the alveolar part of the maxilla. The adult size of sinus varies. It may extend into the zygomatic process or alveolar process of maxilla. It drains into the posterior part of the infundibulum of the middle meatus of the nose.

Ethmoidal sinus: Ethmoidal Labyrinth in the medial wall of orbit has multiple thin walled air spaces which are grouped into anterior, middle and posterior sinuses. Anterior and Middle ethmoidal cells open into the infundibulum of middle meatus while posterior ethmoidal sinus drains into superior meatus.

Sphenoidal sinuses: There are 2 sphenoidal sinuses separated by thin septum in the sphenoid bone. It is the most variable cavity and difficult to approach. This sinus is surrounded by vital structures like internal carotid artery, optic nerve and vidian canal. The ostium of the sinus lies in the anterior wall and opens into sphenoethmoidal recess behind superior concha.

Frontal sinus: It lies in diploic space between outer and inner tables of frontal bone. Two frontal sinuses are unequal in size and extent and are separated by bony septum in the mid line. The sinus drains *via* frontal recess into middle meatus (62%) or into infundibulum (38%).

Radiological Anatomy of paranasal sinus

The axial plane of CT scan identifies basal lamella of middle turbinate which is the dividing point of anterior and posterior ethmoidal sinus.

Sphenoidal sinus is assessed by a reliable landmark of ostium which lies 1 cm superior to posterior inferior end of superior turbinate and 1.5 cm superior to concha (Kennedy DW et al. 1988). It also evaluates pneumatization of Sphenoidal sinus and its relation with internal carotid artery and optic nerve.

The boundaries of frontal sinus are demarcated by anteriorly agar nasi cells, posteriorly ethmoidal bulla and skull base while laterally by lamina papyracea and medially by middle turbinate.

Anatomical variation of sinus seen by CT scan

Maxillary hypoplasia

it is an uncommon condition which may be misdiagnosed as chronic sinusitis and failure to recognise this can injure medial orbital wall (Y Ramakrishnan et al. 2011) (Figure 1).

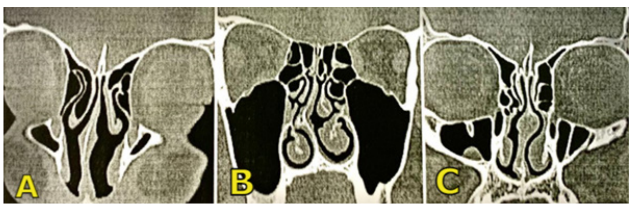

Figure 1. (A) Maxillary sinus hypoplasia, (B) Septal spur with maxillary hyper pneumatisation, (C) Left maxillary septation.

It is classified as,

Type 1(Mild sinus hypoplasia): It has normally developed an uncinate process, well developed infundibular passage and varying degree of mucosal thickening of affected sinus.

Type 2 (Significant sinus hypoplasia): It shows hypoplastic or absent uncinate process, ill-defined or absent infundibular passage and total opacification of affected sinus.

Type 3 (Profound sinus hypoplasia): Sinus is represented by a shallow cleft in the lateral wall of nose and absent uncinate process.

Maxillary sinus hyperpneumatization: It is seen as extension of sinus into alveolar margins, zygomatic bone or rarely into hard palate (Table 1).

Table 1. Showing number and frequency of variant of maxillary sinus Frontal sinus-Out of 200 patients, 37 subjects (18.5%) had hypoplastic (Non/ poorly pneumatized). 31 subjects (15.5%)of them showed bilateral and 6 (3%) were showing right-sided hypoplasia. Intra frontal cells were seen in 64 (32%) subjects. Out of them 26 (13%) on the right side and 24 (12%) on the left side while 14 (7%) bilateral. Extension of pneumatization into crysta gali seen in 16 (8%) subjects and into orbital roof in 6 (3%) subjects.

Maxillary sinus	Right	Left	Bilateral	Total	Frequency
Normal size				183	91.50%
Hypoplasia	9			9	4.50%
Over pneumatisation	8			8	4.00%
Septation	7	9	7	23	12.50%

Frontal sinus hypoplasia: It can be recognised by poor or non- pneumatized sinuses in adults. It can be dominant, unilateral or bilateral hypoplastic or very rarely bilateral aplastic.

Ethmoidal sinus variant: keros classification is used to measure its variations (Moore KL, et al 1998).The length of lateral lamella and cribriform plate defining type of olfactory fossa. It has three types depending on the depth of the cribriform plate below fovea ethmoidalis.

The pneumatization of ethmoidal cells extends into the anterior roof of maxillary sinus along the floor of orbit. Anterior ethmoidal cells reach lacrimal fossa inferolaterally. Posterior ethmoidal cells extend posterior, lateral and superior to sphenoidal sinus.

Sphenoidal sinus hypoplasia: The pneumatization is limited to anterior end of tuberculum sellae

Sphenoidal sinus pneumatisation. It has 3 types,

conchal (area below the sellar), presellar (not beyond the anterior end of sellar), sellar (extend into body of sphenoid beyond floor of sellar till clivus)

Hyperpneumatization of Sphenoidal sinus extends into pterygoid, clinoid, greater wing of sphenoid. It may be unilateral or bilateral.

Embryology of paranasal sinuses

The paranasal sinuses develop and enlarge after birth; ethmoid and sphenoid sinus becomes significant after age of 5-7 years while frontal sinus develops last and becomes of significant size by adolescent age. Developmentally nose and paranasal sinuses are interlinked. At the end of 4 weeks of development, branchial arches, pouches and primitive gut make their appearances (Table 2).

Table 2. Showing number and frequency of variant of Frontal sinus Ethmoidal sinus-Ethmoidal sinus was evaluated for accessory ethmoidal air cells. The commonest were ondi cells noted in 51 (25.5%) subjects.

Frontal sinus	Right	Left	Bilateral	Total	Frequency
Normal size				148	74.00%
Hypoplasia	6	0	31	37	18.50%
Hyper pneumatisation	0	0	15	18	7.50%
Intra frontal cells	26	24	14	64	32.00%

Inferior projection form lateral wall of nose form maxillary sinus along with inferior turbinate. Superior projection form lateral wall of nose from ethmoidal air cells with superior and middle turbinate. The frontal sinus develops as a direct continuation of embryonic infundibulum of frontal recess superiorly during 16th week. It remains as blind sac within the frontal bone till 2 years of age and then complete pneumatization occurs by age of 9 years (Table 3).

Table 3. Showing number and frequency of variant of Extramural Ethmoidal cells in Ethmoidal sinus Sphenoidal sinus-Out of 200 subjects, 9 (4.5%) had hyperplasia and 21 subjects (10.5) had hyperpneumatization. Septation in sinuses were seen in 61(31.5%) subjects. Out of them 21 (10.5%) on right side, 15 (7.5%) on left side and 25 (12.5%) showed bilateral. Extension of sphenoidal sinus observed in pterygoid process in 10 (5%) subjects with right sided extension (1) left sided (4) and bilateral (5). Extension into Greater wing of sphenoid bilaterally in 8 subjects and left side in 3 subjects. Extension into anterior clinoid process seen in 10 subjects (5%). Out of which bilateral extension in 6 subjects and unilateral on the left side in 4 subjects.

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Ethmoidal sinus	Right	Left	Bilateral	Total	Frequency
Agar nasi	15	9	11	35	17.50%
Ondi cells	13	15	23	51	25.50%
Haller cells	10	4	24	38	19.00%

Development of maxillary sinus: The embryonic infundibulum invades the maxillary process to form primitive maxillary sinus. The pneumatization of maxillary sinus is faster than frontal sinus (Table 4).

Table 4. Showing number and frequency of variant of Sphenoidal sinus.

Sphenoidal sinus	Right	Left	Bilateral	Total	Frequency
Normal size				170	85.00%
Hypoplasia				9	4.50%
Over pneumatisation				21	10.50%
Septation	21	15	25	61	31.50%

Thus frontal, maxillary and ethmoidal sinuses arise from invagination of lateral nasal wall whereas sphenoidal sinuses arise from posterior invagination of nasal capsule materials (Table 5).

Table 5. Showing number and frequency of Extension of pneumatisation of Sphenoidal sinus.

Extensions	Right	Left	Bilateral	Total	Frequency
Pterygoid	1	4	5	10	5.00%
Sphenoid	0	3	8	11	5.50%
Clinoid	0	4	6	10	5.00%
Mixed				4	2.00%

MATERIALS AND METHODS

This study is a prospective observational study. The study was conducted on randomly selected 200 normal human adult male and female above 12 years of age who were referred for CT scan of paranasal sinuses in the hospital over the period of 2 years from December 2015 to November 2017. The patients with Sinonasal anatomy alteration or obscuration due to inflammatory disease, previous Sinonasal surgery, facial trauma, paranasal sinus neoplasms and younger age below 12 years were excluded from study. The formalities such as protocol maintenance and ethical issues were cleared by institution level formed ethical committee with proper documentation. The consent form of standardised format designed as per current study requirement.

After taking proper consent, examination was done on a 64 slice GE (General Electronics) CT scanner which yields precise high resolution reconstruction of anatomical structure. After taking scout images to confirm the correct position, baseline images were taken in axial sections. Then multiplanar reformations of these baseline images were arranged in coronal and sagittal sections (Figure 2).

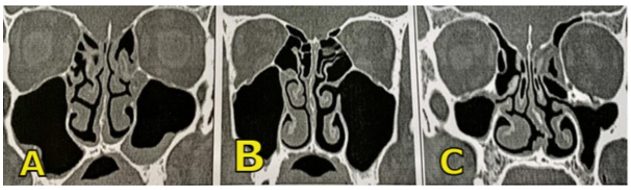

Figure 2. (A) Hyperpneumatisation, Right maxillary sinus extending to hard palate, (B) Extending to Right maxillary alveolar ridge, (C) Asymmetry of pneumatisation of maxillary sinuses with mild hypoplasia on Right side.

On Axial, Coronal and Sagittal CT scan following parameters were studied,

Maxillary sinus

1. Size-Normal, Hypoplasia/Poor pneumatization, Non-pneumatization, Asymmetric pneumatisation
2. Hyperpneumatization
3. Septae- Present/Absent

Frontal sinus

1. Normal hypoplasia-Hypo or non-pneumatisation
2. Hyperpneumatization/extension
3. Septation- Present/Absent
4. Intra- frontal or Supraorbital cells

Ethmoidal sinus Complex

1. Extramural Agar nasi cells-Present/Absent
2. Hellar cell
3. Ondi cells

Sphenoidal sinus:

1. Size- Normal, Hypoplasia or non-pneumatization
2. Hyperpneumatization
3. Septation- Present/Absent

OBSERVATIONS AND RESULTS

As this is a prospective type of study, the data recorded on data sheets and observations of tables were compared with previous studies.

About 200 patients above 20 years of age referred for CT scan of paranasal sinuses during December 2015 to November 2017 were selected randomly. Children below 12 years of age were excluded from the study.

Maxillary sinus-Out of 200 subjects, 9 subjects (4.8%) showed bilateral hypoplasia and 8 subjects (4%) showed bilateral hyperpneumatization. Septation seen in 23 subjects (12.5%) of which 7(3.5%) subjects had bilateral Septa and 16(8%) subjects had unilateral septation in the right or left maxillary sinus (Figure 3).

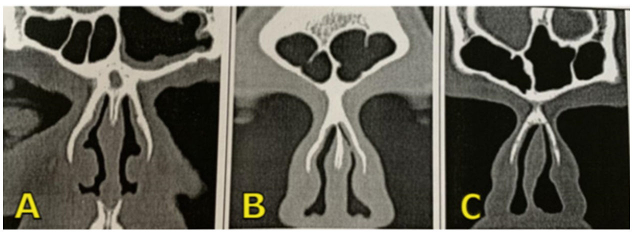

Figure 3. (A) Right frontal septation, (B) Bilateral frontal Septation, (C) Left frontal Septation.

DISCUSSION

Anatomical variations are best viewed and appreciated in coronal plane CT scan. In variations next to Deviated nasal septum, anatomical variation of paranasal sinus is common finding on CT scan such as pneumatized middle concha, supraorbital cells, sphenoidal septations, onodi cells (Hudgins P, et al. 1993). Other less common variations are hypoplastic frontal sinus, paradoxical middle turbinate.

Paranasal sinus anatomical variations lead to recurrent sinusitis mainly due to impaired sinus drainage and ventilation. So understanding different variations and location of paranasal sinuses are important. In paranasal sinuses, asymmetry in size and shape of maxillary sinus is common. Extension of pneumatization of maxillary sinus towards palatine, alveolar and zygomatic recesses may be found. R.C. Onwachekwa et al found maxillary hypoplasia in (0.91%) population. Hyperpneumatization/extension of maxillary sinus seen in (4%) population and septation of maxillary sinus observed in (6.36%) population. He also noted hypoplasia of frontal sinus in (3.64%), Extensive pneumatization in (0.91%) and hypoplasia in (10.6%) (RC Onwuchekwa, et al. 2017). Zhang et al noted supraorbital ethmoidal cells which are simulating multiple frontal sinuses in (5.4%) population. Extension of pneumatization of spheniodal sinus in anterior clinoid process was observed in (6.3%) according to RC onwachekwa et al. same pneumatization was recorded by Bolger et al. in (13%) individual (Kennedy DW, et al. 1987). As findings in this study showed that Anatomical variation in paranasal sinuses are very common and computed tomography of gold standard method of diagnosis performs fundamental role in radiologic investigation of paranasal sinuses. It is used as a tool for diagnosing Sino-nasal lesion, for pre and post-surgical assessment of patients. It has capability in delineating anatomic variant in paranasal sinuses which protects essential structures around paranasal sinuses against iatrogenic injuries (Driben JS, et al. 1998). It also prevents recurrent diseases from extramural cells. So anatomic variant awareness of paranasal sinuses such as pneumatization of anterior clinoid process, supraorbital cells, infraorbital cells, ethmoidal cells, pneumatization of dorsum sellae is required. Failure to recognise these variants may be associated with a higher rate of surgical complications. The present anatomic variants make a person susceptible to narrowing of sinus outflow followed by Residual diseases with incomplete clearances and predispose the person for development of recurrent rhinosinusitis (Anik I 2005, Lingaiah RKN 2016). Thus the knowledge of these variants help Otorhinologist, Radiologist to evaluate CT scan of paranasal sinuses better in endoscopic examination, FESS surgeries and making therapeutic decisions. Computed Tomography of paranasal sinuses improve the visualisation of paranasal sinus anatomy and allows great accuracy in evaluating paranasal sinus diseases (Daniel V, et al. 2021). Anatomic variation studied on CT scan are found to block the OMC and cause chronic sinusitis. The blockade in the OMC (Osteomata complex) leads to impaired drainage of maxillary, frontal and anterior ethmoidal sinus causing chronic sinusitis. Thus the Radiologist must pay close attention to variants and provide road map to surgeons for avoiding possible complications (A Peric, et al. 2010).

CONCLUSION

The three dimensional CT Scan imaging in axial, coronal and sagittal plane is modality of choice to evaluate these variants as conventional radio graph do not provide adequate information due to structural superimposition. Identification of these variants play an important role in locating site and severity of obstruction to paranasal sinuses outflow, guiding the surgeons pre-operatively and preventing iatrogenic complications (Weinberger DG et al. 1996). There is scarce evidence in the literature regarding the effects of common viral respiratory infections in the paranasal sinuses (Gupta S, et al. 2016). Sinonasal symptoms in SARS-CoV-2 positive patients are generally considered to be rare when compared to lower respiratory tract symptoms 16. Since this is a preliminary study, our aim is to use study findings in the future with large sample size for any relation of anatomic variants of paranasal sinuses with present complication of mucormycosis in post-COVID patients.

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