REVIEW ARTICLE OPEN ACCESS

Use of Computed Tomography for Nasal and Paranasal Anatomic Variants

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ABSTRACT

Augmentations and improvements in sinus surgical methods and computed tomography (CT) have concurrently elaborated interest in variable anatomical features of the nasal cavity and paranasal sinuses (PNS). 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 modifications. By the broad perspective of anatomical features in the sinonasal area, certain anatomical characteristics are supposed to be a risk factor for the advancement of sinus pathological conditions and hence it should be essential for the radiologist to be conscious of the variable anatomical structures residing within the nasal and PNS area, significantly if the treatment plan includes surgical procedures. The sinonasal tomographic imaging is required in symptomatic subjects of sinusitis to evaluate the mysterious sinonasal anatomy including morphology, variations, detailed bony visualization, and pathologies within the sinonasal region and surroundings. This review includes studies from 2013-2023 which were extracted from searching databases like Google Scholar, Internet sources, PubMed, Scopus, and Medline to establish a critical review of hidden anatomy of nasal and paranasal sinus region, detected by computed tomography and highlight the operative significance to enhance the surgical outcomes globally.

Keywords: Sinonasal, Computed Tomography, Nasal Cavity, Paranasal Sinus.

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INTRODUCTION

The nasal and paranasal sinus (PNS) structures (Figure 1) are important regions of distinct interest in various medical fields including the maxillofacial-surgery, and otorhinolaryngology. The PNS, which are carefully concealed, have repeatedly confused the anatomists and medical experts of the past years. Probably, because these structures are closely connected to many important organs of the body, for example, the brain, eyes, nose, and mouth, many unusual schemes about their purpose have been established for years. The sinuses were considered a mysterious area of a skull by previous anatomists. Historically, it was first recognized 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 enhancements to an understanding of complex anatomy.[1] The pathological changes within nasal and PNS are often of greater interest to radiologists than anatomical variations. But the anatomical variable features

of the upper respiratory tract, that is nasal and PNS, are greatly significant because of their vital responsibility in the drainage pathway of the osteo-meatal-complex (OMC) and ventilatory sinus functioning. Thus, anatomical variants of the sino-nasal region elevate the risk of sinus-mucosal diseases. Furthermore, anatomical variations can affect the consequences and safety of surgical procedures performed in the sino-nasal region such as functional-endoscopic-sinus-surgery (FESS).[1-5] This review includes studies from 2013-2023 which were extracted from different databases. The aim of the review was on hidden anatomy of the nasal and paranasal sinus region, detected by computed tomography and highlighting the operative significance to enhance the surgical outcomes globally.

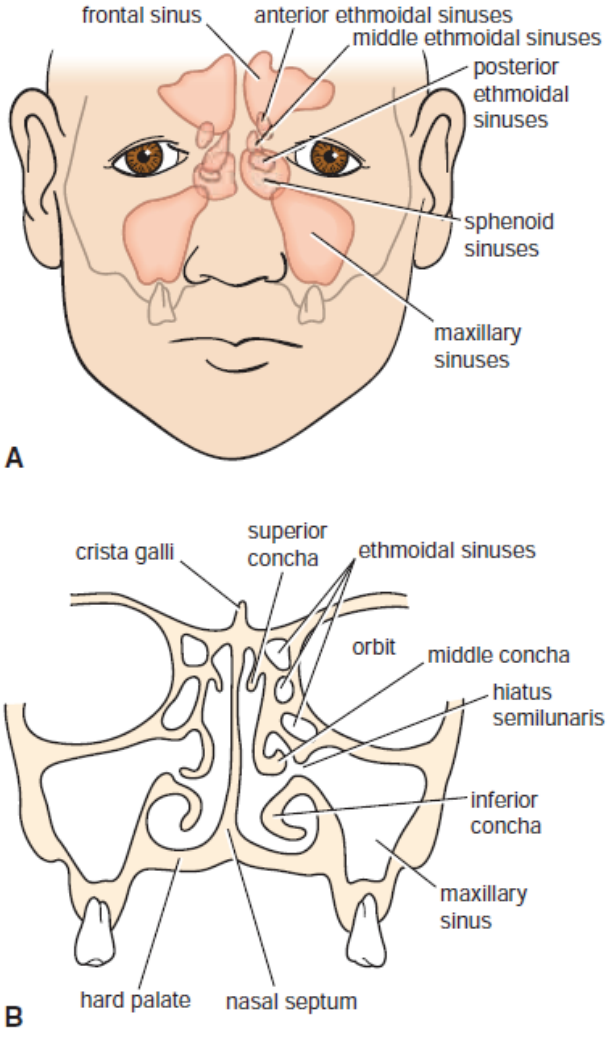

Figure 1: (A) The position of the paranasal sinuses in relation to the face. (B) Coronal section showing the nasal cavity[1]

DISCUSSION

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 the sinonasal region are also frequently observed, and they play a vital role in the dysfunctional drainage of sinus cavities. Computed tomography (CT imaging) is important to evaluate various pathologies of the nasal cavity and PNS. It allows us to assess the fine bony details related to the nasal cavity and PNS, anatomical variants, and disease progress of the sinonasal region. The CT imaging technique is now established as the overall best method for the evaluation of patients who are suspected of having complex anatomy and any aggressive lesion of the sinonasal region.

Sinonasal Framework

For a strong understanding of structural anatomy and variations of nasal and PNS regions, it is valuable to appreciate the various anatomical characteristics and relationships of these structures to their surroundings. The lateral wall of the nasal cavity contains several structural characteristics and

recesses that are critical for the extensive understanding of PNS morphology, such as nasal turbinates which are three to four bony shelves, and the three nasal meatuses which are spaces situated below each nasal turbinate. The sphenoid and posterior ethmoid sinuses drain into the superior meatus. The middle nasal meatus present between the superior and inferior recesses receives sinus drainage from the frontal, maxillary, and anterior ethmoid.

The lower inferior nasal meatus receives drainage from the nasolacrimal duct. The sickle-shaped thin bony structure called uncinate process is a part of the ethmoid bone, which is sheathed by mucoperiosteum, situated medial and lateral to the ethmoid infundibulum and middle turbinate respectively. There is a pyramidal space called the ethmoid infundibulum, which helps in facilitating the drainage of the frontal, anterior ethmoid, and maxillary sinuses. The uncinate process (UP) and ethmoid bulla have a gap in between called semilunar hiatus, that empties the ethmoid infundibulum. The osteo-meatal complex (OMC) is situated near the middle turbinate laterally posses openings of various sinuses like maxillary, ethmoid, and frontal. This is a collection of various anatomical features located within the middle nasal meatus like the uncinate process, middle meatus itself, infundibulum, frontal, maxillary, ethmoid sinuses, and anterior ethmoid air cells along with sinus ostia[6-9].

Sinonasal Anatomical Variants and Sinusitis

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 (UP) and ethmoidal anatomical variations. [10-12] The DNS was the most common anatomical variant found in patients (48.8%) with acute/chronic or recurrent sinusitis. The structures like agger-nasi-cells and CB were almost similarly frequent (30.7%), and infraorbital cells or Haller cells were noticed in 11.5%. The UP anatomical variants were noticed in 18.2%, and the large prominent ethmoid bulla was seen in 10%[10]. The significance of anatomic structural variations requires attention in that way that these variations can impair the normal sinus drainage process of the associated sinus, which could result in various pathologies like inflammatory sinus diseases such as sinusitis. Generally, the anatomy varies from individual to individual globally and anatomical structural variations are harmless and are not diseases however, it may exist as an incidental finding in people with sinus infections[10-12]. The mucosa lining of the PNS is prone to infection and inflammation. Previously, Hippocrates specified that "In a person having a painful spot in the head, with intense headaches, pus or fluid running from the nose removes the disease" which may be described as sinusitis. It is the inflammation/swelling of the mucosal coating of paranasal sinuses (PNS), and the gaps that secrete mucus which is needed for the whole nasal passage to work effectively. This inflammatory condition called sinusitis is one of the most observed illnesses of the upper respiratory tract. The prevalence of sinusitis noticed globally says that it affects one in seven adults resulting in approximately fifty million individuals being diagnosed as patients of sinusitis annually[13-15]. This disease is increasing dramatically in epidemic proportions all over the globe. The conditions like chronic sinusitis and recurrent sinusitis have been recognized to influence adversely health-related quality of life within the community[16].

Computed Tomography Significance for Anatomical Variants Evaluation

With the invention of FESS and CT, significant attention has been directed toward 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[17-19]. Harmless anatomical variations are considered normal and can be present in any individual. The importance of anatomical variants can't be ignored as the presence of various anatomical variants produces a diversity of relationships to the structure in which they lie. The Sino nasal cavities possess a multitude collection of anatomic variants, few of which are significantly common and observed in most people. In 2015 it was revealed that there was no noteworthy difference in the prevalence of variable anatomical features of PNS or nasal cavity between patients with mild sinus disease progress versus moderate to severe sinus mucosal disease. However, evaluation of diverse anatomical variants in every routine CT-PNS obtained for rhinosinusitis is of significant worth except surgery is aimed. Importantly, for cases who are intending to undergo FESS or other skull base surgery, however, the caregivers need to be aware of variants, such as onodi cells, supraorbital cells, infraorbital Haller cells, and many others. There are chances of a higher rate of surgical complications if variants are overlooked[19-26].

In the last few years, the most useful sinus surgical technique called functional endoscopic sinus surgery (FESS) has developed a gold standard, especially in the treatment of recurrent or chronic rhinosinusitis. Therapeutic outcomes rely on the preoperative evaluation of the patients. The radiologic CT scanning of the PNS displays appropriate sensitivity and good specificity for the early diagnosis of pathologies like rhinosinusitis and the detection of anatomical variations of the sinonasal region. And the pre-FESS evaluation workup is globally

recommended to provide detailed visualization of normal, variable, and pathological structures of the sinonasal region. Surprisingly, one study reported that variations are common in chronic rhinosinusitis, and which are possibly associated with localized chronic rhinosinusitis as compared to diffuse one which involves a majority of the sinuses. Further stated that the anatomical variations are not associated with the incidence of polyps. Moreover, computed tomography helps to reflect the disease severity, also, to some extent, the symptoms. Combination of medical history, physical examination, and in addition to it CT may increase the accuracy of diagnosing various sinus pathologies for instance rhinosinusitis[27-29].

With the invention of new surgical modalities like FESS and new radiologic investigations like CT scanning, significant consideration has been directed toward the morphology of the nasal and PNS area. Comprehensive knowledge of anatomical variations in the PNS area is of crucial value for caregivers executing sinus surgery along with radiologists that are concerned with the patient's preoperative work-up. 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 the sinonasal region are also frequently observed, and they play a vital role in the dysfunctional drainage of sinus cavities, generally resulting in acute sinusitis followed by chronic sinusitis[30-36]. A study concluded that variants were highly prevalent on computed tomography of nasal and paranasal structures and the frequently observed variant was a septal deviation most of the patients had more than one variant present, also those subjects were more at risk to develop sinusitis[37]. Surprisingly similar studies were observed by another author who observed septal deviation as the most common anatomical variant and the occurrence of multiple anatomical variations in most of the patients. Moreover, in contrast to other studies, the author reported that the prevalence of anatomical variations does not describe the establishment of disease progress but may predispose it to operative complications. Hence, radiologists play a crucial role to identify and detect anatomical variants to provide a clear pathway to surgeons and reduce the chances of operative complications[38]. Interestingly, one study stated that nasal and paranasal symptoms in SARS-CoV-2 positive subjects are usually rare when compared to the lower respiratory symptoms. But supporting the practice of computed tomography for the evaluation of nasal and paranasal structures for proper visualization[39]. The paranasal structures 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 to the preoperative evaluation of the patients, 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 which is the gold standard in the study of complicated structures, for providing accurate information on soft tissues, bony regions, and the presence of air cells, thus characterizing a highly sensitive method of imaging[39-43].

Highlights of Nasal and Paranasal Anatomical Variations From 2015-2023

Nowadays increasing interest in FESS has put the characteristic distinguishable nasal and paranasal anatomy in the spotlight. Now in recent years, research about the 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 territory can cause sinus drainage obstruction, therefore becoming the reason for various sinus mucosal infections. Presently the modality of choice for the evaluation of nasal structures, sinuses along with its nearby relations, is computed tomographic imaging. This imaging technique displays accurate information on both bony and soft tissue details along with the 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 the significance of anatomical variants of the sinonasal region is still controversial. The majority of authors believe that various anatomic variants can cause some way for the occurrence of recurrent rhinosinusitis.

Therefore, it can be summarized that the use of computed tomographic scanning is the best approach to visualize clinically significant anatomy and additionally the disease diagnosis of sinuses and nasal areas. Surgeons learn from their mentors the important instruction of sinus surgeries to spare as much as possible and remove as much as required. The choice of investigation for the patients who are expected for surgical interventions like FESS is computed tomography. It will assist the surgeons to visualize the anatomic structural features residing within the nasal and paranasal areas. Therefore, it is labeled as a ''ROAD MAP OF FESS''. The paranasal sinuses are critically important having complex

anatomical variations, and variable anatomical relations, hence CT scan is advisable for all patients who are undergoing surgical intervention, to prevent dreadful complications.[39-40] The detailed workup of some previous studies from 2015 to 2023 is compiled in Table-1.

Table 1: Previous studies from 2015 to 2023 including detailed workup on sinonasal structures and association with sinusitis.

Author and year	Study Design (n)	Methodology	Statistical analysis	Gender (M/F)	Age (years)	Outcome	Association with sinusitis
Tiwari & Goyal (2015)[19]	A prospective cross-sectional (85)	CT-scan PNS and nasal endoscopy	Not mentioned	58/27	10- 50	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
Suri, Janardan& Parmar, (2016)[20]	A prospective cross-sectional (120)	CT-scan,	Fischer's exact test	NA	> 18	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%	Positive association
Alsowey et al., (2017)[10]	Prospective study, n=240 ,	MSCT scanner and endoscopic evaluation	McNemar test and the kappa (K)	138/102	20-61	DNS=48.8% Agger nasi= 30.6% CB=30.6% Haller cells=11.2% UP variations=18.1% Large ethmoid bulla=10%	No association
Espinosa, Genito & Ramos, (2018)[21]	Retrospective study (60)	CT -scan	NA	43/17	>18	Agger nasi =78.4% Haller cells= 41.60% DNS=20.1% CB= 11.70%	Positive Association
Mathuram et al., (2019)[22]	Prospective study (200) ,	128-MDCT	Fischer's exact test	116/ 84	11-60	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

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Nautiyal et al., (2020)[23]	Retrospective study (250)	CT-scan	NA	150/100	18-82	Middle nasal turbinates 30.73%, Agger nasi cells=21.6%, Haller cells=22.9%, Septal-deviation=21.9%, Septate sphenoid-sinus=20.2%	No association
Qureshi and Usmani (2021)[9]	Prospective study (50)	CT-scan,	Pearson-correlation	34/16	18-60	Agger-nasi cells=66%, DNS=59%, CB=40%, Haller cells=15%, Onodi cells=13%	Positive association
Qureshi et al., (2022)[24]	Prospective study (50)	CT-scan	Pearson-correlation	34/16	18-60	Agger-nasi cells=64.0% DNS=56.0%, CB=46.0% Haller cells=10.0%, Onodi cells=10.0%	Positive association
Hubballi and Lyngkhoi (2022)[25]	Prospective study (100)	CT scan,	Chi-square test	64/36	< 20>60	Septate sphenoid sinus=100%,	Positive association

n=number of subjects, M=male, F=female, NA: not available

Computed tomography (CT), Concha bullosa (CB), Deviated Nasal Septum (DNS), Functional Endoscopic Sinus Surgery (FESS), Osteo-meatal complex (OMC), Paranasal sinuses (PNS)

CONCLUSION

The prevalence of anatomical variations is quite common globally and septal deviation is the most frequent variant and multiple variations are more commonly observed, importantly which makes them more vulnerable to sinus pathologies. Researchers across the globe have appreciated the use of computed tomography of a sinonasal region in every patient of sinonasal pathology to provide a clear road map to health care professionals for better therapeutic strategies, surgical outcomes, and enhancing the quality of life within the community.

CONFLICTS OF INTEREST

No conflicts of interest to declare.

AUTHORS' CONTRIBUTION

All authors equally worked on the literature search and drafting of the manuscript.

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