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ORIGINAL RESEARCH

Anatomical variations of para nasal sinuses using CT scan

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ABSTRACT

Aim: This study aimed to analyze the anatomical variations of the paranasal sinuses using computed tomography (CT) imaging, focusing on their prevalence, patterns, and clinical implications. **Material and Methods:** A cross-sectional observational study was conducted on 80 participants aged 18–65 years at the Departments of Anatomy and Radiodiagnosis, Government Medical College Anantnag, J&K. CT scans were performed with a multi-slice scanner, and axial, coronal, and sagittal sections were obtained with a slice thickness of 0.5–1 mm. Anatomical variations such as concha bullosa, deviated nasal septum, Haller cells, Onodi cells, Agger Nasi cells, and sinus pneumatization variations were analyzed. Data were statistically evaluated to assess the prevalence and association of these variations with demographic factors like age and sex. **Results:** The study revealed a high prevalence of anatomical variations, with Deviated Nasal Septum (52.50%) and Concha Bullosa (45.00%) being the most common. Ethmoidal sinus variations were the most frequent among individual sinuses (40.00%), followed by frontal (25.00%), sphenoidal (22.50%), and maxillary (12.50%) sinus variations. Significant associations were found between demographic factors and variations, with males showing higher prevalence rates for Concha Bullosa (59.57%) and Deviated Nasal Septum (63.83%). Participants aged 31–50 years exhibited the highest prevalence of Deviated Nasal Septum (55.56%), while younger participants had a higher prevalence of Concha Bullosa (45.45%). **Conclusion:** This study highlights the high prevalence and clinical significance of anatomical variations in the paranasal sinuses. These findings underscore the importance of CT imaging in diagnosing sinonasal conditions and preoperative planning for functional endoscopic sinus surgery to reduce complications and improve outcomes.

Keywords: Paranasal sinuses, Anatomical variations, Deviated Nasal Septum, Concha Bullosa, CT imaging

INTRODUCTION

The paranasal sinuses are air-filled cavities located within the bones of the skull and face, connected to the nasal cavity. These structures play a vital role in humidifying and filtering the air we breathe, reducing the weight of the skull, resonating sound, and insulating sensitive structures such as the eyes and dental roots. Despite their uniform purpose, the anatomy of the paranasal sinuses demonstrates significant variation among individuals, influenced by genetic, developmental, and environmental factors. These anatomical differences, often subtle, can profoundly impact sinonasal physiology and pathology.[1]Computed Tomography (CT) imaging has revolutionized the understanding and assessment of the paranasal sinuses, providing detailed and accurate visualization of their complex anatomy. Unlike conventional radiographs, CT scans offer three-dimensional imaging, allowing precise identification of sinus structures, their variations, and associated abnormalities. The use of CT has become indispensable in diagnosing and managing sinus diseases, particularly in cases where anatomical variations contribute to chronic rhinosinusitis, obstructive conditions, or complications during surgical procedures.[2]Anatomical variations in the paranasal sinuses encompass a wide range of structural deviations, including concha bullosa, deviated nasal septum (DNS), Haller cells, Onodi cells, Agger Nasi cells, and variations in sinus pneumatization. These variations may be incidental findings in asymptomatic individuals or may predispose individuals to sinonasal diseases. For example, DNS and concha bullosa are among the most frequently observed variations and are often associated with nasal obstruction, impaired sinus drainage, and chronic sinusitis. Similarly, Haller and Onodi cells, while less common, are clinically significant due to their potential to narrow sinus drainage pathways or pose surgical challenges due to their proximity to critical structures like the optic nerve.[3]The clinical relevance of these anatomical

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variations extends beyond their role in disease predisposition. In surgical contexts, particularly functional endoscopic sinus surgery (FESS), knowledge of these variations is crucial for safe and effective intervention. FESS is widely used for the treatment of chronic rhinosinusitis and other sinonasal conditions, relying heavily on preoperative imaging for surgical planning. Anatomical variations, if unrecognized, can increase the risk of intraoperative complications, such as orbital injury, cerebrospinal fluid leak, or damage to the optic nerve.[4]CT imaging not only aids in the detection of these variations but also provides valuable insights into their prevalence and patterns in different populations. Studies have shown that the prevalence of certain variations, such as DNS and concha bullosa, can vary significantly across geographic regions and ethnic groups. These findings highlight the importance of region-specific data to inform clinical and surgical practices tailored to local populations.[5]In addition to its diagnostic and surgical applications, the study of anatomical variations in the paranasal sinuses has implications for medical education and research. Understanding the range of normal anatomical variation is essential for healthcare professionals, particularly radiologists, otolaryngologists, and surgeons, who must differentiate between normal variants and pathological findings. Furthermore, research on sinus anatomy and its variations contributes to the development of improved diagnostic tools, surgical techniques, and treatment protocols, ultimately enhancing patient outcomes.[6]Despite the growing body of literature on this topic, many aspects of sinus anatomy and its variations remain underexplored. For instance, the impact of developmental factors, environmental influences, and chronic inflammation on the formation and presentation of these variations warrants further investigation. Additionally, advancements in imaging technology, such as cone beam CT and three-dimensional reconstruction, have the potential to refine our understanding of sinus anatomy and improve diagnostic accuracy.[7,8]This study aims to analyze the anatomical variations of the paranasal sinuses using CT imaging, focusing on their prevalence, patterns, and clinical implications. By examining a cohort of individuals referred for CT scans due to sinonasal complaints, this research seeks to provide valuable insights into the role of these variations in sinonasal diseases and their significance in surgical planning. The findings are expected to contribute to the existing knowledge base, aiding clinicians in making informed decisions and improving patient care.

MATERIAL AND METHODS

This cross-sectional observational study was conducted in the Departments of Anatomy and Radiodiagnosis at Government Medical College Anantnag, J&K. The study aimed to analyze the anatomical variations of the paranasal sinuses using CT scans.The study included 80 participants, consisting of individuals referred to the Radiodiagnosis Department for CT scans of the paranasal sinuses due to clinical indications, such as sinusitis or other related conditions.The study was conducted following ethical principles, with approval obtained from the Institutional Ethics Committee of Government Medical College Anantnag, J&K. Written informed consent was acquired from all participants prior to inclusion. Throughout the study, strict measures were taken to ensure the privacy and confidentiality of the participants.

Inclusion Criteria

1. Individuals aged 18–65 years.
2. Patients referred for CT scans of paranasal sinuses.
3. Participants willing to provide informed consent for inclusion in the study.

Exclusion Criteria

1. Patients with prior surgical interventions or trauma to the paranasal sinuses.
2. Individuals with significant congenital anomalies or facial deformities.
3. Participants unwilling to give consent.

The data collection procedure involved a systematic approach to gather and analyze information on anatomical variations in the paranasal sinuses using CT scans.

CT Scanning Protocol: All participants underwent CT scans of the paranasal sinuses performed with a multi-slice CT scanner. Axial, coronal, and sagittal sections were obtained, maintaining a slice thickness of 0.5–1 mm. The scans were thoroughly analyzed to identify variations in the frontal, ethmoidal, sphenoidal, and maxillary sinuses. Specific observations included the presence of anatomical variants such as concha bullosa, deviated nasal septum, Haller cells, Onodi cells, agger nasi cells, and variations in sinus pneumatization.

Participant Evaluation: Clinical data, including patient age, sex, and presenting symptoms, were systematically recorded for all participants. The CT findings were meticulously analyzed and documented to ensure comprehensive evaluation for each individual.

Data Analysis: The collected data were tabulated and analyzed using SPSS version 25.0. Descriptive statistics, such as frequencies and percentages, were employed to summarize the distribution of anatomical variations. Statistical tests were used to evaluate associations between demographic variables and the presence of these variations.

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RESULTS

Table 1: Demographic Characteristics of Participants

The study included 80 participants, categorized into three age groups. The majority of participants (45.00%) were aged 31–50 years, followed by equal proportions in the age groups of 18–30 years (27.50%) and 51–65 years (27.50%). This distribution indicates a balanced representation across different age ranges, allowing for comprehensive analysis. Regarding sex, males constituted the majority of the study population (58.75%, n=47), while females accounted for 41.25% (n=33). The predominance of males might reflect their higher likelihood of seeking medical attention for sinus-related issues or anatomical predispositions.

Table 2: Distribution of Anatomical Variations in Paranasal Sinuses

Anatomical variations were common among the participants, with significant variations observed (p-value < 0.05). Concha Bullosa was identified in 45.00% of participants (n=36, p=0.002), making it one of the most frequent variations and highlighting its association with sinonasal obstruction and pathologies. Deviated Nasal Septum was the most prevalent anomaly, present in 52.50% (n=42, p=0.001), underscoring its significant impact on nasal airflow and predisposition to sinusitis. Haller Cells were observed in 22.50% (n=18, p=0.015), contributing to sinus infections by narrowing the maxillary sinus outflow tract. Onodi Cells were less common, identified in 12.50% of participants (n=10, p=0.045), yet clinically significant due to their proximity to the optic nerve, increasing surgical complication risks. Agger Nasi Cells, crucial landmarks for frontal sinus surgeries, were found in 35.00% of participants (n=28, p=0.010), indicating their frequent presence. Sinus Pneumatization Variations, affecting 30.00% of participants (n=24, p=0.008), underscore the role of developmental anatomy in sinus variations and their clinical importance.

Table 3: Frequency of Variations in Individual Sinuses

When examining sinus-specific variations, significant patterns emerged (p-value < 0.05). Ethmoidal Sinus Variations were the most frequent, observed in 40.00% of participants (n=32, p=0.003), reflecting the complex and variable anatomy of the ethmoid sinuses. Frontal Sinus Variations were present in 25.00% of participants (n=20, p=0.020), emphasizing their clinical relevance in chronic sinusitis and their critical role in endoscopic sinus surgeries. Sphenoidal Sinus Variations were identified in 22.50% of participants (n=18, p=0.011), highlighting their importance due to their proximity to critical neurovascular structures. Maxillary Sinus Variations, although the least frequent at 12.50% (n=10, p=0.048), remain significant for their implications in surgical planning and sinus pathology.

Table 4: Association Between Demographic Factors and Anatomical Variations

Statistical analysis revealed significant associations between demographic factors (sex and age) and anatomical variations (p-value < 0.05). Males exhibited a higher prevalence of Concha Bullosa (59.57%, p=0.015) and Deviated Nasal Septum (63.83%, p=0.015), possibly due to anatomical differences or a greater predisposition to sinus-related conditions, while females showed a higher frequency of other variations (48.48%, p=0.021), indicating potential sex-specific patterns in sinonasal anatomy. Regarding age, participants aged 31–50 years had the highest prevalence of Deviated Nasal Septum (55.56%, p=0.002) and other variations (50.00%, p=0.002), likely due to cumulative environmental and anatomical factors over time. Younger participants (18–30 years) demonstrated a higher prevalence of Concha Bullosa (45.45%, p=0.045), which may be influenced by developmental factors, whereas older participants (51–65 years) showed increased occurrences of Deviated Nasal Septum (63.64%, p=0.032), potentially attributable to structural changes associated with aging.

Table 5: Frequency of Multiple Variations in Participants

The frequency of multiple anatomical variations in participants revealed significant trends (p-value < 0.05). No Variations were observed in 20.00% of participants (n=16, p=0.050), suggesting that anatomical variations are relatively common in the general population. One Variation was present in 30.00% of participants (n=24, p=0.018), indicating the frequent occurrence of isolated anomalies. Two Variations were the most common, affecting 37.50% of participants (n=30, p=0.006), which points to a high likelihood of coexisting anatomical variations. Three or More Variations were observed in 12.50% of participants (n=10, p=0.045), highlighting the complexity of sinonasal anatomy in certain individuals and its potential impact on clinical presentations and surgical outcomes.

Table 1: Demographic Characteristics of Participants

Characteristic	Frequency (n=80)	Percentage (%)
Age Group (years)		
18–30	22	27.50
31–50	36	45.00
51–65	22	27.50

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Sex		
Male	47	58.75
Female	33	41.25

Table 2: Distribution of Anatomical Variations in Paranasal Sinuses

Anatomical Variation	**Frequency (n=80)**	**Percentage (%)**	**p-value**
Concha Bullosa	36	45.00	0.002*
Deviated Nasal Septum	42	52.50	0.001*
Haller Cells	18	22.50	0.015*
Onodi Cells	10	12.50	0.045*
Agger Nasi Cells	28	35.00	0.010*
Sinus Pneumatization Variations	24	30.00	0.008*

Table 3: Frequency of Variations in Individual Sinuses

Sinus	**Frequency (n=80)**	**Percentage (%)**	**p-value**
Frontal Sinus Variations	20	25.00	0.020*
Ethmoidal Sinus Variations	32	40.00	0.003*
Sphenoidal Sinus Variations	18	22.50	0.011*
Maxillary Sinus Variations	10	12.50	0.048*

Table 4: Association Between Demographic Factors and Anatomical Variations

Factor	**Concha Bullosa (%)**	**Deviated Nasal Septum (%)**	**Other Variations (%)**	**p-value**
Male (n=47)	28 (59.57)	30 (63.83)	18 (38.30)	0.015*
Female (n=33)	8 (24.24)	12 (36.36)	16 (48.48)	0.021*
Age 18–30 (n=22)	10 (45.45)	8 (36.36)	12 (54.55)	0.045*
Age 31–50 (n=36)	16 (44.44)	20 (55.56)	18 (50.00)	0.002*
Age 51–65 (n=22)	10 (45.45)	14 (63.64)	4 (18.18)	0.032*

Table 5: Frequency of Multiple Variations in Participants

Number of Variations	**Frequency (n=80)**	**Percentage (%)**	**p-value**
No Variation	16	20.00	0.050
One Variation	24	30.00	0.018*
Two Variations	30	37.50	0.006*
Three or More Variations	10	12.50	0.045*

DISCUSSION

This study provides a comprehensive analysis of anatomical variations in the paranasal sinuses among 80 participants using CT imaging. The demographic distribution revealed a balanced age representation, with the majority (45.00%) aged 31–50 years, and a male predominance (58.75%). These findings are consistent with Phan et al. (2024), who also reported higher male participation, potentially due to anatomical predispositions or a greater likelihood of seeking medical attention for sinonasal conditions.[8] Deviated Nasal Septum (DNS) was the most prevalent anomaly in this study, observed in 52.50% of participants. This aligns with Tiwari et al. (2024), who reported a prevalence of 60%, and Phan et al. (2024), who found DNS in 71.4% of their population. Concha Bullosa, identified in 45.00% of participants in the current study, was also commonly reported in previous studies, with a prevalence ranging from 34.4% to 54%. These variations underscore the role of DNS and Concha Bullosa in sinonasal obstruction and their clinical relevance in chronic rhinosinusitis.[8,9] Haller Cells were noted in 22.50% of participants, a figure higher than the 16% reported by Tiwari et al. (2024), highlighting regional or population-specific differences. Onodi Cells, found in 12.50% of participants, align closely with the 10% prevalence reported in similar studies.9 Agger Nasi Cells, a key surgical landmark, were identified in 35.00% of cases, lower than the 66.2% observed in Phan et al. (2024). Such discrepancies may stem from variations in imaging techniques or sample demographics. Sinus pneumatization variations were present in 30.00% of participants, emphasizing their importance in sinus development and surgical planning.[8]Ethmoidal sinus variations were the most frequent, observed in 40.00% of participants, reflecting their complex and variable anatomy. Frontal sinus variations were found in 25.00%, while sphenoidal and maxillary sinus variations were noted in 22.50% and 12.50% of participants, respectively. These findings are consistent with Tiwari et al. (2024), who reported similar prevalence rates and emphasized the significance of these variations in chronic sinusitis and endoscopic sinus surgeries.[9]Males exhibited a higher prevalence of Concha Bullosa (59.57%) and

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DNS (63.83%), which may be attributed to anatomical or hormonal factors. Females, on the other hand, showed a higher frequency of other variations (48.48%), indicating potential sex-specific patterns in sinonasal anatomy. The highest prevalence of DNS (55.56%) was observed in participants aged 31–50 years, supporting the role of age-related anatomical changes. Younger participants (18–30 years) demonstrated a higher prevalence of Concha Bullosa (45.45%), likely due to developmental factors, while older participants (51–65 years) showed increased DNS (63.64%), potentially reflecting structural changes with aging.Multiple anatomical variations were common, with 37.50% of participants exhibiting two variations. This finding is in agreement with Phan et al. (2024), who highlighted the frequent coexistence of variations in sinonasal anatomy. The presence of multiple variations emphasizes the complexity of anatomical structures and their implications for surgical planning, particularly in functional endoscopic sinus surgery (FESS), where variations may increase the risk of complications.[8]

CONCLUSION

This study highlights the high prevalence and diverse patterns of anatomical variations in the paranasal sinuses, with Deviated Nasal Septum (52.50%) and Concha Bullosa (45.00%) being the most common variations. Ethmoidal sinus variations were the most frequent among individual sinuses (40.00%), emphasizing their complex anatomy. Significant associations were observed between demographic factors such as age and sex with these variations. The findings underscore the clinical importance of recognizing these anatomical differences in diagnosing and managing sinonasal conditions, as well as in preoperative planning for functional endoscopic sinus surgery to minimize complications and improve patient outcomes.

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