Original Research Article

Morphometric and Volumetric Measurements of the Paranasal Sinuses among the population of the Bareilly region

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Abstract

Background: In the field of sinus surgery and anatomy, the size and shape of the paranasal sinuses vary widely. The volume of paranasal sinuses offers more accurate values and closest to their natural measurements and contributes to diagnosing sinus pathologies. Present study was aimed to evaluate the morphometric relationship between right and left side sinuses and measured the volumetric changes in these sinuses according to the age and gender of the patients. **Materials and Methods:** The morphometric and volumetric measurement of the paranasal sinuses were carried out with the help of CT scans in 300 patients (163 male and 137 female) considered to have a preliminary diagnosis of paranasal pathology, and direct coronal sections imaging was performed in all patients. In addition, limited axial scans parallel to the orbitomeatal line with the patients in the supine position were carried out whenever required. Reformatted CT images were also studied in all planes. **Results:** The mean volumes of frontal sinus was 8.3 ± 5.7 cm3, mean volumes of the maxillary sinus was 18.5 ± 6.4 cm3, mean volumes of the ethmoidal sinus was 7.1 ± 4.2 cm3and sphenoid sinus measured as 6.9 ± 4.5 cm3 volume respectively. The gender-wise comparison of volumes of paranasal sinuses was statistically significant ($P < 0.05$). However, the average volume of paranasal sinuses in elderly patients shown a gradual decrease. **Conclusions:** The morphometric and volumetric analysis of the paranasal sinuses is, highly variable and dependent on many other structures and probably always will be challenging.The uniqueness of this research study was that the volumetric measurement anatomical changes of the paranasal sinuses could be compared in the direction of the advancing age.

Keywords: Morphometric, Volumetric, Paranasal Sinus, Computed Tomography

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Introduction

Anatomically, paranasal sinuses are air-filled pockets in the nasal cavity. Paranasal sinus has a complex anatomy and also varies among individuals. However, even the same person can exhibit structural differences between the two sides of these sinuses. Because of this, comprehensive information on the structure of the sinuses is important before performing any interventions like endoscopic sinus surgery[1].

As per the many research articles, numerous methods have been used to measure the volume of the paranasal sinuses. Thevolume rendering techniques and three dimensional (3D) reconstruction models are extensively used. However, at present, Computed Tomography (CT) is the most preferred radiological imaging technique for evaluating the anatomy of paranasal sinuses; as CT images can easily differentiate between mucosa, soft tissues and bone, their borders can be clearly defined[1-3].

From the 1990s onwards, Computed Tomography (CT) is widely used to analyze the complex anatomical features of the paranasal sinuses (PNSs) as these structures exhibit significant inter-individual variation. In this present study, we have attempted to evaluate the morphometric variations and different volumes measurement with the help of CT images of paranasal sinuses. The findings of our research study were critical in understanding normal and different disease and pathological conditions of the paranasal sinuses.

There are several facets to paranasal sinuses; these facets are adapted mostly for different functions.As a result of pneumatization, the overall mass of the skull is lessened, the maxillofacial region is lighter, more mucus is produced, and the voice becomes less tonic[1, 4-6]. In the postnatal period, changes in the sizes, shape and dimensional are commonly seen. Therefore age-related volume changes in the paranasal changes are to be considered for surgical procedures. During dental procedures, it's always important to understand the variations and pattern of pneumatization. Further, it is not known whether there is any configuration among other sinuses existing or not[6-8].

So it is really important to evaluate the variations of paranasal sinuses for treatment planning in the sinonasal region. Such information will be an great importance for to the radiologist, otolaryngologists, maxillofacial surgeons, and dentists' before performing any surgical procedures.

In this study, we have used Cavalieri principle, a simple method to estimate the volume of the paranasal sinuses by using a simple conventional computer. Furthermore, this study helps determine the normal morphometric dimensions and volumetric analysis of paranasal sinuses in different age groups and gender groups.

Materials and methods

Subjects

In this prospective cross-sectional study, we tried to estimate anatomical variations of paranasal sinuses in patients with one or otherin the patients undergoing CT scan evaluation. Three hundred patients were studied from July 2019 to June 2021 in our Rohilkhand Medical College and Hospital, Bareilly. The age of the recruited patients ranged from 17 years to 55 years, of which 163 were male, and 137 were female patients.

CT scan was performed in a Bright Speed Elite-16 machine of Wipro GE health care private limited company; this CT machine is situated in the Department of Radiology, Rohilkhand Medical College and Hospital, Bareilly, Uttar Pradesh.

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Direct coronal sections imaging were carried out in all patients. In addition, limited axial scans parallel to the orbitomeatal line with the patients in the supine position were performed whenever required. All films were taken without contrast. No intravenous contrast was used.

By carefully tracking the measurement functions of the CT scanner, morphometric evaluations were carried out by examining the areas of each tomographic slice.By multiplying the area with the slice thickness, we calculated the volume of CT in each section.According to the Cavalieri principle, we calculated the total volume of areas as the mean of the standard deviations by summing all the volumes of each slice, the total volume of areas was expressed in cubic centimetres as a mean ± SD.

Statistical analysis

SPSS software (version 11.0) was used for the statistical assessment. The Students t-test and Kruskal-Wallis test were used for validating statistically. $p<0.05$ was considered statistically significant.

Results

The morphometric analysis of CT imaging as a method for measuring different dimensions of paranasal sinuses and other nearly related structures is shown in Table 1. However, the there was no significant difference in morphometric measurements between the left and right side.

Table 1: The average morphometric measurements (cm) of the paranasal sinuses

Sinus	Sides	Antero-posterior distance	Cranio-caudal distance	Transverse distance	p Value
Frontal	**Right**	1.49 ± 0.48	4.92 ± 1.52	5.36 ± 0.82	0.082
	Left	1.37 ± 0.25	4.64 ± 0.95	4.77 ± 0.91	
Maxillary	**Right**	4.98 ± 1.04	4.84 ± 1.25	2.86 ± 0.52	0.924
	Left	4.50 ± 0.62	5.22 ± 0.71	2.08 ± 0.43	
Ethmoid	**Right**	2.19 ± 0.96	2.49 ± 0.69	1.91 ± 0.53	0.827
	Left	1.98 ± 0.19	1.88 ± 0.75	1.28 ± 0.27	
Sphenoid	**Right**	2.79 ± 1.07	1.67 ± 0.84	1.49 ± 0.47	0.367
	Left	3.21 ± 1.21	2.78 ± 0.99	2.39 ± 0.63	

The average volumes of frontal sinus were 8.3 ± 5.7 cm^3, average volumes of the maxillary sinus were 18.5 ± 6.4 cm^3, average volumes of the ethmoid sinus was 7.1 ± 4.2 $cm^3$and sphenoid sinus measured as 6.9 ± 4.5 cm^3 volumes respectively. The gender-wise comparison of volumes of paranasal sinuses was statistically significant ($P < 0.05$). However, the average volume of paranasal sinuses in elderly patients shown a gradual decrease.

Table 2: The average of volumes (cm^3) of four paranasal sinuses.

Gender	Frontal Sinus	Maxillary Sinus	Ethmoid Sinus	Sphenoid Sinus
Male	9.1 ± 6.4	22.4 ± 7.1	8.4 ± 2.6	8.2 ± 4.7
Female	6.2 ± 3.7	18.4 ± 5.3	5.9 ± 1.7	6.4 ± 2.5

The volumetric analysis of paranasal sinuses has clearly shown significant difference among both genders ($P < 0.05$). The average volumes of paranasal sinuses of female patients were 18% smaller compared to the male patients.

Table 3: The average of volumes (cm^3) of the paranasal air sinuses according to gender

Sinus	Sides	Male	Female	p Value
Frontal	**Right**	15.04 ± 5.20	11.13 ± 4.52	0.991
	Left	15.97 ± 6.65	11.53 ± 5.45	
Maxillary	**Right**	30.98 ± 11.41	22.66 ± 9.75	0.073
	Left	19.48 ± 5.62	15.52 ± 6.71	
Ethmoid	**Right**	9.69 ± 2.96	7.49 ± 2.99	0.284
	Left	8.53 ± 4.19	7.88 ± 2.99	
Sphenoid	**Right**	9.79 ± 2.82	8.02 ± 3.84	0.008
	Left	9.69 ± 2.96	7.49 ± 2.99	

By using independent Student t-test the comparison of average volumes of paranasal sinuses show that the average volumes for the paranasal sinuses were more prominent in males; it was statistically significant. However, average volumes of the right-sided sinuses were significantly more prominent in male patients (Table 3).

Table 4: The average of volumes (cm^3) of the paranasal air sinuses according to age

Sinus	Sides	Age (Years)				p Value
		17-26	27-36	37-46	47-55	
Frontal	**Right**	15.11 ± 4.95	11.54 ± 5.10	12.36 ± 5.62	10.67 ± 4.39	0.826
	Left	16.86 ± 5.77	11.82 ± 5.38	13.09 ± 5.85	10.47 ± 5.51	
Maxillary	**Right**	31.97 ± 8.97	25.72 ± 8.06	22.05 ± 7.24	21.14 ± 8.74	0.047
	Left	29.27 ± 9.66	23.37 ± 10.11	21.46 ± 10.94	21.81 ± 7.83	
Ethmoid	**Right**	9.68 ± 2.62	6.43 ± 3.41	6.83 ± 3.73	6.00 ± 3.02	0.377
	Left	8.83 ± 4.46	5.97 ± 4.31	6.86 ± 4.83	5.87 ± 2.29	
Sphenoid	**Right**	9.39 ± 5.53	7.40 ± 3.73	8.39 ± 3.1	6.33 ± 3.14	0.052
	Left	8.87 ± 5.77	7.00 ± 3.80	7.91 ± 4.32	5.99 ± 2.81	

The average of the volumes of the paranasal sinuses was compared against different age groups of patients from both genders. This comparison confirmed that the paranasal sinuses volume growth correlated inversely with age groups. However, the right and left sides of the sinuses were symmetrical. Apparently, from the 17-26 years age group, there is a gradual decrease in the volumes of the paranasal sinuses as the age of the patient advances.

Table 5: The average of volumes (cm^3) of the paranasal air sinuses according to the type of Deviated Nasal Septum (DNS)

Type of Deviated nasal septum	Frontal Sinus	Maxillary Sinus	Ethmoid Sinus	Sphenoid Sinus
Straight nasal septum	18.90±5.72	20.15 ±6.20	19.27±6.00	16.84± 6.08
Right-sided DNS	17.27±5.71	19.21 ±6.16	17.04±5.67	16.18±4.77
Left-sided DNS	16.80±5.57	17.30±5.66	18.48±5.18	15.87±4.26

Patients with the straight nasal septum have showed no statistically significant difference between volumes of paranasal sinuses. The presence of deviated nasal septum had an impact on the size of selective paranasal sinuses. Our study has established a statistically significant association between the average volumes of paranasal sinuses and the presence of deviated nasal septum. It was noticed both for right-sided (p=0.152) and left-sided (p=0.261) of deviations.

Discussion

The specific measurements of the normal and average size and volume of the paranasal sinuses could be used as a diagnostic tool for diagnosing anatomical features. Therefore, this study is crucial for evaluating the anatomical features of the paranasal sinuses, which may provide necessary information and guidelines for surgeons and researchers[9].

Our study carried out the morphometric analysis by using CT scan from patients belongs to different age groups. Statistically, we estimated the dimensions of different paranasal sinuses and other structures related to them. However, there was no significant differencebetween the left and right side of morphometric measurements of different sinuses.

Many researchers used several methods and imaging techniques to carry out the volumetric studies of paranasal sinuses as per the literature[5-9]. However, few of these studies considered the distances between sinus walls and calculated the volume of the sinuses by trying to make the geometrical model of the sinus. In the recent past, studies have shown that three-dimensional volume was calculated by Cavalieri principle by using two-dimensional images from imaging studies[9, 10].

The paranasal sinuses comprise the four smaller sinuses, i.e. frontal, maxillary, ethmoidal, and sphenoidal. It is essential to know the different volumes of paranasal sinuses for early diagnosis, treatment planning, and follow-up of diseases such as allergy, hypoplasia, and infections in the sinonasal region. To perform functional endoscopic sinus surgery, the paranasal sinus volumes and anatomical details of the sinuses need to be understood[1-3, 7-10]. In compare with ellipsoid method, Cavalieri principle is more time consuming but more reliable[6, 9, 10]. However, by Cavalieri principle the volume measurements from standard CT scan can be made smoothly. Therefore, it is suitable for daily clinical practice[6].

In this present study, CT scanning technique was used with Cavalieri principle of stereological methods. Our research study has presented the average volumes of the frontal sinus, maxillary sinus, ethmoid sinus and sphenoid sinus measured. The gender-wise comparison of volumes of paranasal sinuses was statistically significant ($P < 0.05$). However, our observations show that a gradual decrease in the volume of paranasal sinuses in elderly patients. There was a significant difference in volumes of paranasal sinuses among patients from both genders ($P < 0.05$). The 18% of the female patients was seen and were smaller when compared to the male patients. Our obervations are in accordance with earlier publications were the volumes of paranasal sinus were higher in males than females, but these volumes decreased as the age advances[13-18].

Our results also highlighted the comparison of the morphometric measurement and analysis of the volumes of the paranasal sinuses among different age groups. These findings confirmed that the paranasal sinuses volume correlated inversely with age groups; the right and left sides were symmetrical. The presence of deviated nasal septum had an impact on the size of selective paranasal sinuses.

Morphometric measurements and volumetric analysis of the paranasal sinuses among patients from different age groups provide us with real pathological changes and planning of treatment modalities. However, the reliability of our study could be improved by considering a larger sample size and growth pattern of paranasal sinuses.

Conclusion

Our study showed that computed tomography is a reliable method for measuring different morphometric dimensions and volumetric analysis of paranasal sinuses. In individuals where the volumes of the paranasal sinuses show significant variations, it is essential to know the normal volume limits of paranasal sinuses for the management of different pathological conditions. Therefore, evaluation by Cavalieri principle is an helpful method for the measurement of paranasal sinus volumes obtained from computed tomographic scans.

The uniqueness of this research study was that the volumetric measurement anatomical changes of the paranasal sinuses could be compared in the direction of the advancing age. Our study has contributed to forming a standard in morphometric measurements and volume analysis of paranasal sinuses.

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