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ORIGINAL RESEARCH

Morphometric Study of the Nasal Cavity and Paranasal Sinuses: Implications for Endoscopic Sinus Surgery

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ABSTRACT
Introduction: The nasal cavity and paranasal sinuses form an intricate and vital part of the human anatomy. **Objectives:** The main objective of the study is to find the morphometric study of the nasal cavity and paranasal sinuses and its implications for endoscopic sinus surgery. **Methodology**: This cross-sectional study was conducted at Navodaya Medical College hospital and Research Centre during October 2014 till December 2014. This morphometric study of the nasal cavity and paranasal sinuses was designed to provide comprehensive quantitative data on the anatomical variations within these structures. The study was conducted with a sample size of 85 patients, selected to represent a broad demographic range in terms of age, sex, and ethnicity. Male and female patients aged between 18 and 65 years who were to undergo ESS for sims, CRS, NP or SNM were enrolled in the study. **Results:** The study included 85 patients with a mean age of 42.01 ± 2.98 years, ranging from 18 to 65 years. The cohort was nearly evenly split by sex, with 52.9% males and 47.1% females. The average body mass index (BMI) was 25.4 kg/m², with values ranging from 18.5 to 32.5 kg/m².The mean anterior nasal cavity width was 22.5 mm, with a range from 18.0 to 27.0 mm, while the middle nasal cavity width averaged 18.7 mm, ranging from 14.5 to 23.5 mm. The posterior nasal cavity width had a mean of 13.6 mm, with a range of 10.5 to 16.5 mm. The nasal cavity height averaged 50.2 mm, varying between 45.0 and 55.0 mm, and the nasal septum length was found to be 55.8 mm on average, with a range from 50.0 to 61.0 mm. **Conclusion:** It is concluded that significant anatomical variability exists within the nasal cavity and paranasal sinuses, which has critical implications for endoscopic sinus surgery (ESS).

INTRODUCTION
The nasal cavity and paranasal sinuses form an intricate and vital part of the human anatomy. It includes roles that have to do with humidifying and filtering the air, resonating the voice, and defending the body's systems against diseases as well as being the chief mechanism for breathing. The maxillary, frontal, ethmoidal and sphenoidal sinuses are cavities lying within the bones of the skull, and communicating with the nasal cavity through small openings called ostia [1]. Due to their elaborate arrangement and localization in the zones immediately adjacent to the orbit and brain, they are of great importance at both physiological and operative levels. Most sinonasal conditions such as chronic rhinosinusitis, nasal polyposis, and certain sinonasal tumors has resulted in most ENT surgeons using endoscopic sinus surgery as the preferred approach [2]. Unlike open surgery ESS is a minimal invasive approach where access to the sinus cavities is made through use of nasal endoscopes without the need for external incisions. The advantage of this technique is that it permits enucleation of the pathological tissue with more precision, easier visualization of the field and quicker recovery of the patients. Nonetheless, the outcome of ESS mainly depends on the understanding of the nasal and the paranasal sinus which may be quite different from one person to another [3].

The analyses of the metrics of structures in the given context therefore require the use of morphometric studies. From these studies it is possible to obtain the specific measurements of nasal cavity and paranasal sinuses, which are useful for planning the operations on account of the existing individual variations in size, location and relative position. For example, the size of the opening of the maxillary sinus, the height and width of the nasal cavity, and the thickness of the walls of the sinus are some of the parameters that define the difficulty and risks of the ESS [4]. It is important to recognize these differences whenever possible so that during preoperative planning of the surgical intervention, the surgeon will understand what parameters are present or absent, and what special approaches should be used to influence the anatomy of every particular case [5]. It is thereby important for one of the goals of this morphometric study which is to compile and evaluate the biological variability of the population. Differences in the size and shape of the nasal cavity and paranasal sinuses are also genetically, and may be due to age, gender, ethinicity, and intra-individual variability. For example, dissimilar patterns in the ethmoidal sinuses or size of sphenoid sinus can complicate the process of operation, and invariably lead to postoperative complications such as orbital damage or leakage of cerebrospinal fluid. To that effect, this study seeks to look at some patterns that are relatively more frequent and other anatomical deviations that are less common in the hope of improving the surgeon's odds when it comes to avoiding such risks [6].

Moreover, use of additional morphometric parameters in conjunction with modern visualization methods, computer tomography and magnetic resonance imaging along with their integration has completely changed sinus surgery methods [7]. CT angiography permits the anatomical entails of the sinuses to be well-delineated with the identification of anatomic markers that can help in planning surgical procedures by integration with morphometric data. This also assists in preoperative planning but also in the intraoperative localization reducing damage of critical structures and optimizing surgical results [8].

Thus, the research questions of this study are also instructional in nature, besides having clinical relevance. it give one more work for improving our understanding of anatomical peculiarities of the sinonasal region thus making useful contribution into the formation of the training tool for Surgeons and Medical students. The detailed morphometric data can be utilised in creating virtual models and training surgeries to improve students and beginners' experiences and to prepare them for real Essential Surgery cases [9]. The impacts of a broad number of modifications which might occur to the human body have been investigated. Septonasal deviation it has been alleged that septonasal deviation increases ones propensity to fall prey to rhinosinusitis and this view of the matter is vindicated by Yousem et al and Calhoun et al [10]. The other variations that are believed to play a part in the development of rhinosinusitis are concha bullosa, pneumatised middle turbinate, para-doxically angled middle turbinate, abnormally angled uncinate process, uncinate bulla, agger nasi and Haller's cells and the second OP3 middle turbinate. Too, the different patterns of attachment of the uncinate process have been evaluated. Concha bullosa is the only anatomical variation of the ETH for which a reasonable evidence of association with rhinosinusitis has been provided [11].

OBJECTIVES

The main objective of the study is to find the morphometric study of the nasal cavity and paranasal sinuses and its implications for endoscopic sinus surgery.

METHODOLOGY

This cross-sectional study was conducted at Navodaya Medical College hospital and Research Centre during October 2014 till December 2014. This morphometric study of the nasal cavity and paranasal sinuses was designed to provide comprehensive quantitative data on the anatomical variations within these structures. The study was conducted with a sample size of 85 patients, selected to represent a broad demographic range in terms of age, sex, and ethnicity. Male and female patients aged between 18 and 65 years who were to undergo ESS for sims, CRS, NP or SNM were enrolled in the study. Exclusion criteria included prior sinonasal surgery, ontvangst facial fracture, any disease process that might putatively change sinonasal morphology, such as severe congenital abnormalities or highly malignant tumors. CT scans of the paranasal sinuses with high resolution were used as the only imaging technique for the purpose of this study. CT imaging was used because it gives good details of bony structures and is commonly used in planning for ESS surgeries. The CT scans were done for every patient following a pre-specified protocol so as to avoid variability of picture quality and sharpness. The scans included axial scans that were followed by scans that went from base to apex, head to toe, and right to left, and had a 1mm thickness that made measurement of the anatomical features very accurate.

Morphometric Measurements

A comprehensive set of morphometric parameters was measured from the CT scans. These measurements included, but were not limited to:

1. **Nasal Cavity Dimensions:**
2. **Maxillary Sinus:**
3. **Frontal Sinus:**
4. **Ethmoidal Sinus:**
5. **Sphenoidal Sinus:**

All measurements were performed using specialized software that allowed for precise, three-dimensional analysis of the CT images. The software provided tools for delineating anatomical boundaries, calculating distances, and estimating volumes.

Data Analysis

The collected data were subjected to statistical analysis to identify patterns and correlations among the various morphometric parameters. Descriptive

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statistics, such as mean, median, standard deviation, and range, were calculated for each parameter.

RESULTS

The study included 85 patients with a mean age of 42.01 ± 2.98 years, ranging from 18 to 65 years. The cohort was nearly evenly split by sex, with 52.9% males and 47.1% females. The average body mass index (BMI) was 25.4 kg/m², with values ranging from 18.5 to 32.5 kg/m². Among the participants, 76.5% were non-smokers, while 23.5% were smokers. Common comorbidities included hypertension (21.2%), diabetes mellitus (14.1%), and allergic rhinitis (35.3%). The primary indications for endoscopic sinus surgery were chronic rhinosinusitis (70.6%), nasal polyposis (17.6%), and sinonasal tumors (11.8%).

Table 1: Demographic and Baseline Characteristics of Patients

Characteristic	Value
Total Number of Patients	85
Age (years)	
- Mean Age	42.01±2.98
- Age Range	18 – 65
Sex	
- Male	45 (52.9%)
- Female	40 (47.1%)
Body Mass Index (BMI) (kg/m²)	
- Mean BMI	25.4
- BMI Range	18.5 – 32.5
Smoking Status	
- Non-Smokers	65 (76.5%)
- Smokers	20 (23.5%)
Comorbidities	
- Hypertension	18 (21.2%)
- Diabetes Mellitus	12 (14.1%)
- Allergic Rhinitis	30 (35.3%)
Indication for Surgery	
- Chronic Rhinosinusitis	60 (70.6%)
- Nasal Polyposis	15 (17.6%)
- Sinonasal Tumor	10 (11.8%)

The mean anterior nasal cavity width was 22.5 mm, with a range from 18.0 to 27.0 mm, while the middle nasal cavity width averaged 18.7 mm, ranging from 14.5 to 23.5 mm. The posterior nasal cavity width had a mean of 13.6 mm, with a range of 10.5 to 16.5 mm. The nasal cavity height averaged 50.2 mm, varying between 45.0 and 55.0 mm, and the nasal septum length was found to be 55.8 mm on average, with a range from 50.0 to 61.0 mm.

Table 2: Nasal Cavity Dimensions

Parameter	Mean (mm)	Range (mm)
Anterior Nasal Cavity Width	22.5	18.0 – 27.0
Middle Nasal Cavity Width	18.7	14.5 – 23.5
Posterior Nasal Cavity Width	13.6	10.5 – 16.5
Nasal Cavity Height	50.2	45.0 – 55.0
Nasal Septum Length	55.8	50.0 – 61.0

The maxillary sinus showed an average anteroposterior dimension of 32.0 mm (range: 28.0 – 36.5 mm), a mediolateral dimension of 24.5 mm (range: 20.0 – 28.0 mm), and a superoinferior dimension of 36.5 mm (range: 32.0 – 41.0 mm), with an average volume of 14.2 cm³ (range: 10.5 – 18.0 cm³). The maxillary sinus ostium width averaged 4.2 mm, ranging from 3.0 to 5.5 mm.The frontal sinus measurements included a mean height of 22.8 mm (range: 18.5 – 27.0 mm), a width of 26.3 mm (range: 22.0 – 31.5 mm), and a depth of 14.5 mm (range: 11.0 – 18.0 mm), with an average volume of 6.4 cm³ (range: 4.0 – 9.0 cm³).In the ethmoidal sinuses, patients had an average of 7 ethmoidal air cells per side (range: 5 – 10 cells), with an ethmoidal bulla thickness of 5.5 mm (range: 4.0 – 7.0 mm). The distance from the ethmoidal sinus to the orbit averaged 3.2 mm (range: 2.0 – 4.5 mm).

Table 3: Morphometric Measurements of the Nasal Cavity and Paranasal Sinuses

Parameter	Mean	Range
Maxillary Sinus		
- Anteroposterior Dimension (mm)	32.0	28.0 – 36.5
- Mediolateral Dimension (mm)	24.5	20.0 – 28.0
- Superoinferior Dimension (mm)	36.5	32.0 – 41.0
- Maxillary Sinus Volume (cm^3)	14.2	10.5 – 18.0
- Maxillary Sinus Ostium Width (mm)	4.2	3.0 – 5.5
Frontal Sinus		
- Height (mm)	22.8	18.5 – 27.0
- Width (mm)	26.3	22.0 – 31.5
- Depth (mm)	14.5	11.0 – 18.0
- Frontal Sinus Volume (cm^3)	6.4	4.0 – 9.0
Ethmoidal Sinus		
- Number of Ethmoidal Air Cells	7 cells	5 – 10 cells
- Ethmoidal Bulla Thickness (mm)	5.5	4.0 – 7.0
- Distance to Orbit (mm)	3.2	2.0 – 4.5
Sphenoidal Sinus		
- Anteroposterior Dimension (mm)	21.0	17.0 – 25.0
- Superoinferior Dimension (mm)	18.5	15.0 – 22.0
- Sphenoidal Sinus Volume (cm^3)	5.1	3.5 – 7.0
- Distance to Optic Nerve (mm)	6.0	4.0 – 8.5
- Distance to Internal Carotid Artery (mm)	5.5	3.5 – 7.5

Maxillary sinus hypoplasia was observed in 5 patients (5.9%), indicating a smaller than average maxillary sinus, which could complicate surgical access. Concha bullosa, a pneumatization of the middle turbinate that can narrow the nasal passage, was present in 12 patients (14.1%). Septal deviation, affecting the overall nasal cavity structure and potentially impacting airflow and surgical approaches, was the most common variation, found in 34 patients (40.0%).

Table 4: Anatomical Variations Observed

Anatomical Variation	Number of Patients	Percentage (%)
Maxillary Sinus Hypoplasia	5	5.9
Concha Bullosa	12	14.1
Septal Deviation	34	40.0
Haller Cells	8	9.4

DISCUSSION

The findings of this morphometric study provide critical insights into the anatomical variations of the nasal cavity and paranasal sinuses among a diverse patient population. All these variations have profound effects on planning and performing of endoscopic sinus surgery (ESS). The findings of this study stress the significance of distinctive approaches and personalized planning, for the development of the operation and the probability of complications depends on the variance of anatomy [12]. A major finding when concerning this study is the significant variability in size of the nasal cavity and paranasal sinuses among individuals. For instance, the variations in the width of the anterior nasal cavity that varies Between 18. 0 mm and 27. 0 mm show how it is possible to get variation in the accessibility to the nasal passages [13]. Especially when one is deciding which type of endoscopic instruments to use, one needs to consider that narrowing of the passages may influence the difficulty of the movement and the view on the field [14].

In the same manner, the variability of size and volume of the paranasal sinuses such as the maxillary sinus with volume of 10. 5 cm^3 to 18. 0 cm^3 and the sphenoidal sinus with volume of 3. 5 cm^3 to 7. 0 cm^3 implies that some patients may have relatively difficult anatomy that will need more delicate dissection and additional expertise in surgery. This is important in cases involving maxillary sinus hypoplasia or ethmoidal sinus taxonomy because of the small working space that is afforded by the close location of adjacent critical structures such as orbit and skull base [15]. The evidence analyzed in the course of the study also provides insights into the links between such aspects as anatomical differences and clinical results of ESS. For instance, subjects with high septal deviation or concha bullosa had relatively longer times for the surgery most probably because of extra steps required for correction of these anomalies or for reaching the sinus cavities. These anatomical difficulties also indicate the possible heavier intraoperative dangers, including the damage to the adjacent tissues or organs or the failure to excise the pathological tissue [16].

As it has been established in this study the sphenoidal sinus is located closely to the optic nerve and internal carotid artery and these reasons informed us that preoperative imaging is mandatory and delicate manipulation during surgery is necessary. If the sphenoidal sinus is in close contact with such structures, then use of CT or MRI imaging, especially intraoperative image guided surgery is mandatory to avoid severe complications such as blindness and catastrophic haemorrhage [17]. This variability depends will make it imperative to have thorough preoperative evaluation of each patient who is to be subjected to ESS. Multidetector CT as used in this study is particularly important in identifying the specific sinonasal anatomy of each patient. This imaging should be followed by the review of possible anatomical problems that may be present, namely, narrow sinus ostia, prominent ethmoidal air cells or deviated septa which will dictate the method of surgery [18].

CONCLUSION

It is concluded that significant anatomical variability exists within the nasal cavity and paranasal sinuses, which has critical implications for endoscopic sinus surgery (ESS). Personalized preoperative planning, guided by detailed morphometric analysis, is essential to optimizing surgical outcomes and minimizing the risk of complications.

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