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Inferior Turbinate/Nasal Cavity Ratio: A Novel Objective Tool with Potential Clinical Implications

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Abstract

***Background*:** The nasal cavity is the upper part of the respiratory tract which communicates with the external environment through the anterior apertures. It also communicates with the nares, and the nasopharynx via the posterior apertures. The nasal cavity is divided into two by a septum, each cavity consisting of a roof, floor, medial wall, and lateral wall. The nasal cavity is formed laterally by the inferior, middle and superior nasal conchae (turbinates). ***Aim*:** The aim of the study was to investigate the dimensions of the inferior turbinate as seen in selected Nigeria subjects and develop novel anatomical parameters and indices with potential clinical implications. ***Methods*:** This retrospective study was done in the Radiology department of the Rivers State University Teaching Hospital following ethical approval, 339 CT films of adults (males and females) were analysed in this study. Sex and side differences were analysed using t-test, while relationship between anatomical structures were analysed using the Chi square test. The confidence interval was set at 95% and $p < 0.05$ was considered significant. The volume of the inferior turbinate and nasal cavity were measure and the inferior turbinate/nasal cavity ratio was calculated. ***Results*:** The mean volume of the inferior turbinate for males was 2.01±0.12, female was 2.22±0.14 and for the entire population it was 2.12±0.13. The mean volume of the nasal cavity for male and female were 15.98±0.40 cm^3 and 14.73±0.34 cm^3, respectively, whereas the average for the population was 15.35±0.37 cm^3. ***Conclusion*:** To the best of our knowledge, this is the first research that used well defined anatomical landmarks in estimating the volume of the nasal cavity and inferior turbinate. This study also provided a clinically objective tool in assessing the degree of nasal cavity obstruction by providing a grading system for the inferior turbinate/nasal cavity. This tool will particularly be very useful in resource poor settings like ours where nasal endoscopy and rhinometry may not be readily available and affordable. Therefore radiologist can use this grading system to grade the degree of inferior turbinate hypertrophy and predict the degree of nasal obstruction and severity of symptoms.

Keywords: Inferior Turbinate, Nasal Cavity, Ratio, Grading.

INTRODUCTION

The nasal cavity is the upper part of the respiratory tract which communicates with the external environment through the anterior apertures. It also communicates with the nares, and the nasopharynx via the posterior apertures (choanae). The nasal cavity is divided into two by a septum, each cavity consisting of a roof, floor, medial wall, and lateral wall. The nasal cavity is responsible for the humidification of inhaled air and also removal of minute airborne particles and other debris thereby preventing them from getting to the lower respiratory tract. The nasal cavity is formed anteriorly by the anterior nares, laterally by the inferior, middle and superior nasal conchae (turbinates), superiorly by the cribriform plate of the ethmoid bone, inferiorly by palatal processes of the maxilla and horizontal portion of the palatine bone forming the hard palate and posteriorly by posterior nasal aperture (which is also referred to as choanae or posterior nares) at the posterior margin of the bony nasal septum (Knipe and Bell, 2022). The arterial supply to the nose and nasal cavity is from the branches of internal and external carotid arteries. The lateral wall of the nasal cavity is formed by turbinates. There are basically three turbinates; superior (upper), middle and inferior (lower) turbinates. Nevertheless, ocassionally there can be a fourth turbinate which is called the supreme turbinate, located above the superior turbinate (Georgakopoulos and Le, 2019). The inferior turbinate is the largest of the three turbinates and may be as long as the index finger. It is situated at the inferior aspect of the nose extending from the anterior nostril to posterior choana. The turbinate bone is connected to the palate, ethmoid, and lacrimal sac. The inferior nasal turbinate is expansible due to the presence of the submucosal cavernous plexus, especially well developed at its anterior part. The following are trigger factors; allergy, infection, or hormonal changes, causing engorgement of the turbinates. Permanent hypertrophy occurs due to persistent and excessive stimulation (Al-Shouk and Tatar, 2021). The inferior turbinate is responsible for most of the airflow direction, humidification, heating and filtering of air that is through the nose. The inferior turbinate is of immunologic importance because it is the first tissue to come into contact with the outside air. Hence it can trigger innate and adaptive immune reactions (Smith *et al*., 2018). The other two turbinates have similar structures in appearance, but stem from the ethmoid bone, and have no immune function (Dalgorf and Harvey, 2013). Below the inferior turbinate is the inferior meatus which allows for the drainage of the nasolacrimial duct. The inferior turbinate comprise of turbinate bone, mucoperiosteum, soft erectile tissue and mucosa (Matthias, 2007). The inferior turbinate gets its blood is supply from the inferior thyroid artery, a branch of the posterior lateral nasal artery (Al-Shouk and Tatar, 2021). The inferior thyroid artery enters the inferior turbinate at its posterosuperior end, where it divides into two or three branches. It courses through the inferior turbinate in a bony canal wrapped by a fascial coat binding the ITA and canal tightly. This relation is the main reason for the prolonged bleeding following turbinate surgery, as the fascial coat prevents the inferior thyroid artery from contracting (Abdullah and Singh). Nasal obstruction is caused by nasal or septal deformities, and also mucosal disease associated with turbinate hypertrophy. Inferior turbinate hypertrophy is detected in various conditions, such as allergic rhinitis, vasomotor rhinitis, and infectious rhinitis (Aslan, 2013). The aim of the study was to investigate the dimensions of the inferior turbinate as seen in selected Nigeria subjects and develop novel anatomical parameters and indices with potential clinical implications.

MATERIALS AND METHODS

This study was a descriptive cross sectional retrospective study conducted in the Radiology department of the Rivers State University Teaching Hospital (RSUTH), Nigeria between 2022-2024. Ethical approval was obtained from the ethical committee of the Rivers State University Teaching Hospital, 339 adult CT films were retrieved from the archives for this study. Non contrast images were studied and measurements taken (twice for validity) using the digital imaging and communications in medicine viewer for medical images (radiant dicom software) version 23 (Haak *et al*., 2016). CT images of patients who presented with head injury, brain tumors, space occupying lesions, stroke, CT images of the paranasal sinuses were included in this study. Children and adults with poor quality images were excluded from the study.

INFERIOR TURBINATE DIMENSIONS

a. **Maximum Length of Inferior Turbinates**:

The length of the inferior turbinate was measured in anteroposterior view (axial image) as the distance between the highest point of the inferior turbinate and the lowest. The measurements were taken at the point at which both turbinates appear as mirror images of themselves (El-Anwar *et al*., 2017)

Fig. 1: Axial view showing the measurement of the length of the inferior turbinate

b. **Maximum Width of Inferior Turbinates**:

This was measured as the widest horizontal distance of the inferior turbinate. The measurements were taken at the point at which both turbinates appear as mirror images of themselves.

c. **Maximum Height of the Inferior Turbinate:**

This was measured at the where the inferior turbinate attaches to the lateral process of the medial wall of the maxillary antrum. The measurements were taken at the point at which both turbinates appear as mirror images of themselves.

Fig. 2: A and B. Coronal view showing the height and width of the inferior turbinate.

The volume of the inferior turbinate was calculated using the formula below:
Length x Width x Height x 0.52 (Sharma, *et al*., 2014)

DIMENSIONS OF THE NASAL CAVITY

a. Maximum Length of the Nasal Cavity:

Two imaginary horizontal lines (anterior and posterior) drawn from the outer margin of the maxillary bone anteriorly and the posterior margin of the choana. A perpendicular line was then drawn (right and left) to these two lines, these perpendicular lines constituted the length of the nasal cavity.

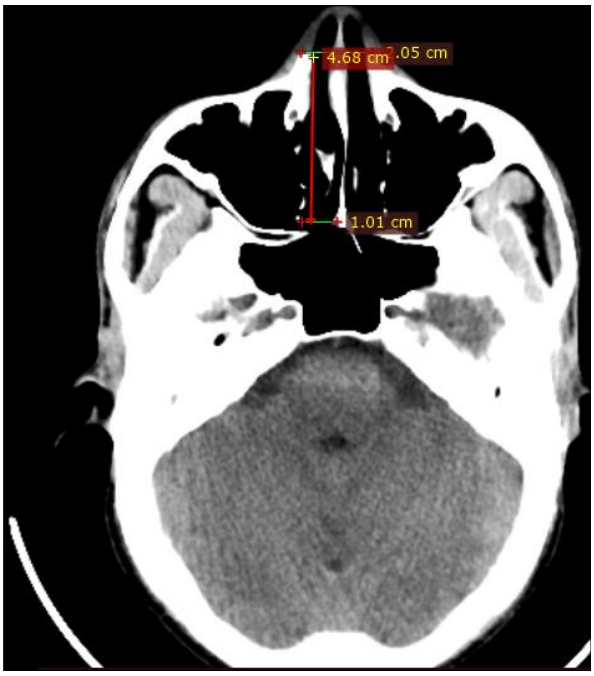

Fig. 3 Axial view showing the length of the nasal cavity

a. **Maximum Height of the Nasal Cavity**: This was measured from the floor of the nasal cavity to the cribriform plate of ethmoid.

b. **Maximum width of the nasal cavity:** It was measured from the nasal septum to the outer margin of the lateral wall of the nasal cavity (bisecting the inferior turbinate).

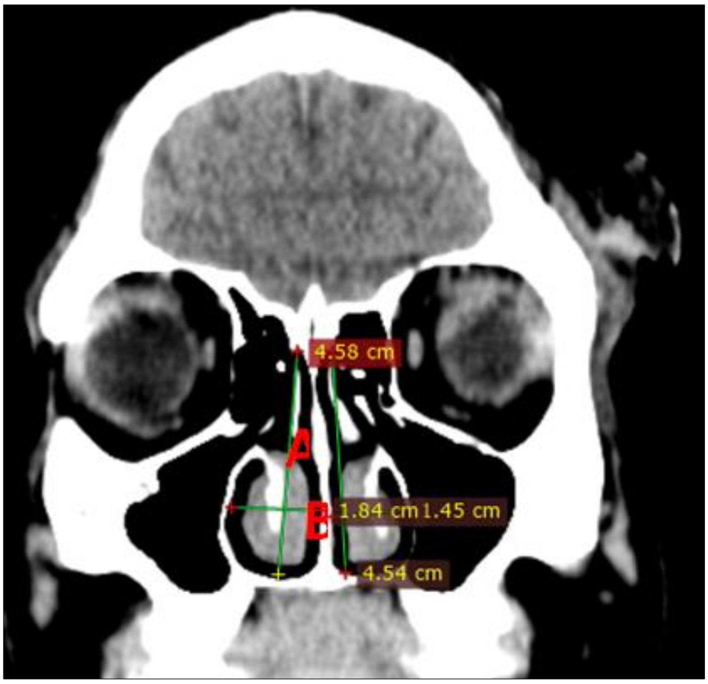

Fig. 4: A and B. Coronal view showing the height and width of the nasal cavity

The volume of the nasal cavity was calculated using the formula below:
Length x Width x Height x 0.52 (Sharma, *et al.*, 2014)

Inferior Turbinate Nasal Cavity Ratio: This was done by calculating the volume of the inferior turbinate that occupies the nasal cavity;

Inferior Turbinate Nasal Cavity Ratio = inferior turbinate/nasal cavity multiplied by 100.

RESULTS

Data were analyzed using statistical package for the social science (SPSS version 23.0) and Microsoft Excel 2020 enterprise edition. Results were presented in Figures, tables, bar chart and pie chart. Continuous variables were presented as Mean ± SED, while categorical variables were presented as pie and bar charts. Sex and side differences were analysed using t-test, while relationship between anatomical structures were analysed using the Chi square test. The confidence interval was set at 95% and $p < 0.05$ was considered significant.

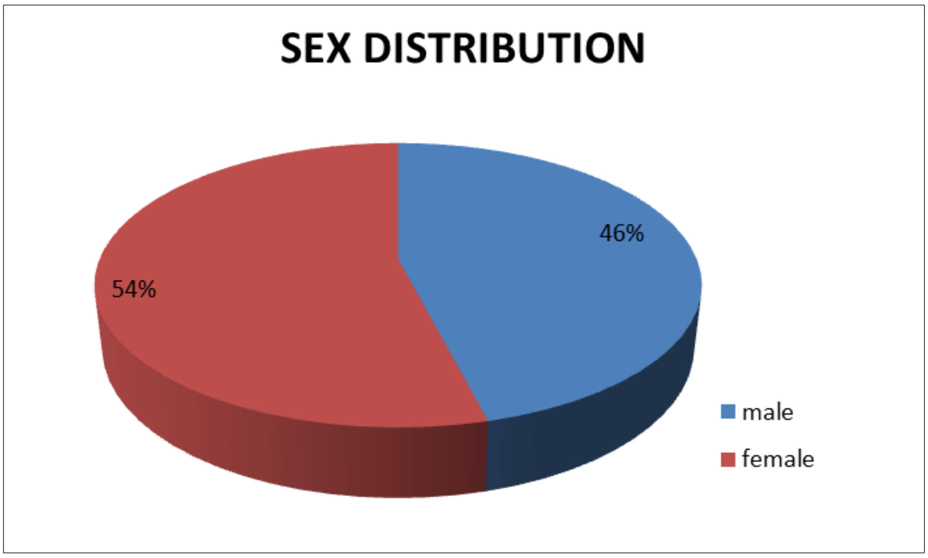

Fig. 5

Table 1: Descriptive statistics of the inferior turbinates dimensions

		N	Mean (mm)	Std. Deviation	Std. Error
AGE	MALE	156	55.15	17.521	1.403
	FEMALE	183	53.27	18.625	1.377
	Total	339	54.14	18.123	.984
RH	MALE (mm)	156	14.3224	4.08375	.32696
	FEMALE	183	13.7634	3.29293	.24342
	Total	339	14.0207	3.68298	.20003
RW	MALE	156	6.9771	2.71238	.21716
	FEMALE	183	7.6187	5.56581	.41144
	Total	339	7.3235	4.48964	.24384
RL	MALE	156	35.696	11.9376	.9558
	FEMALE	183	37.169	11.0223	.8148
	Total	339	36.491	11.4590	.6224
LH	MALE	156	14.2483	3.95822	.31691
	FEMALE	183	13.9579	3.33367	.24643
	Total	339	14.0915	3.63179	.19725
LW	MALE	156	7.0644	4.48063	.35874
	FEMALE	183	7.4004	7.14471	.52815
	Total	339	7.2458	6.05982	.32912
LL	MALE	156	35.0949	11.88519	.95158
	FEMALE	183	37.3513	11.02166	.81474
	Total	339	36.3129	11.46547	.62272

RH *= Right Height,* ***RW****=Right Width,* ***RL****=Right Length,* ***LH****=Left Length,* ***LW****=Left Width,* ***LL****=Left Length.*

Table 1 *shows the mean age (male 55.15*±18, female 53.27±19), mean RH (males and females 14.32±0.32mm and 13.76±0.24mm respectively). RW male 6.98±0.22mm, females 7.61±0.41mm, RL males 35.70±0.10mm, females 37. ±0.81cm. LH males 14.25±0.31mm, females 13.96±0.24; LW males 7.06±0.35mm, females 7.40±0.52mm; LL males 35.09±0.95cm, females 37.35±0.81mm).

Table 2: Paired Samples Statistics

		Mean(cm^3)	N	Std. Deviation	Std. Error Mean(SEM)
	RIGHT VOLUME MALES	2.05	156	1.53	0.12
	RIGHT VOLUME FEMALES	2.21	156	1.50	0.12
	LEFT VOLUME MALES	1.97	156	1.44	0.12
	LEFT VOLUME FEMALES	2.22	156	2.02	0.16

Table 2 Shows mean volume of the inferior turbinate in males and female. The Mean right volume of the inferior turbinate for males 2.05±0.12 (SEM); females 2.21±0.12 (SEM). The mean left volume of the inferior turbinate for males 1.97±0.12 (SEM); females 2.22±0.16 (SEM). There is no statistically significant difference (p value 0.593) between the mean volume of the right inferior turbinate of males and females. Also there is no statistically significant difference (p value 0.919) between the mean volume of the left inferior turbinate of males and females.

Table 3

AVERAGE VOLUME(cm^3) FOR INFERIOR TURBINATE	Means ±SEM
MALES	2.01±0.12
FEMALES	2.22±0.14
Overall Average volume for the population	2.12±0.13

Table 3 shows the mean volume of the inferior turbinate in males (2.01±0.12), females 2.22±0.14, p=0.102. There is no statistically significant difference between the volume of the inferior turbinate in males and females (p>0.05). It also shows the overall mean volume of the inferior turbinate in the studied population 2.12±0.13.

Table 4: Descriptive statistics for Nasal cavity dimensions

		N	Mean (mm)	Std. Deviation	Std. Error
RH	MALE	134	44.428	6.2542	.5403
	FEMALE	166	42.702	5.4225	.4209
	Total	300	43.473	5.8620	.3384
RW	MALE	134	13.756	2.8014	.2420
	FEMALE	166	14.190	2.5779	.2001
	Total	300	13.996	2.6841	.1550
RL	MALE	134	51.007	7.1387	.6167
	FEMALE	166	48.230	6.7093	.5207
	Total	300	49.471	7.0301	.4059
LH	MALE	134	43.596	5.8955	.5093
	FEMALE	166	42.013	5.6147	.4358
	Total	300	42.720	5.7861	.3341
LW	MALE	134	13.376	2.7389	.2366
	FEMALE	166	13.342	2.6573	.2062
	Total	300	13.357	2.6896	.1553
LL	MALE	134	51.007	7.1387	.6167
	FEMALE	166	48.242	6.7197	.5216
	Total	300	49.477	7.0344	.4061

Table 4 The mean mean RH (males and females 44.42±0.54mm and 42.70±0.42mm respectively). RW male 13.76±0.24mm, females 14.19±0.20mm, RL males 51.00±0.61mm, females 48.23 ±0.52mm. LH males 43.60±0.50mm, females 42.01±0.44; LW males 13.38±0.24mm, females 13.36±0.21mm; LL males 51.00±0.62mm, females 49.48±0.52mm).

Table 5: Volume of the nasal cavity

		Mean (cm^3)	N	Std. Deviation	Std. Error Mean
	RVM	16.4545	134	4.85858	.41972
	LVM	15.5009	134	4.41760	.38162
	RVF	15.3422	166	4.43112	.34392
	LVF	14.1098	166	4.18075	.32449
	RVF	15.8687	134	4.57977	.39563
	RVM	16.4545	134	4.85858	.41972
	LVF	14.5172	134	4.31340	.37262
	LVM	15.5009	134	4.41760	.38162

RVM= *Right volume male,* ***LVM****=Left volume male,* ***RVF****=Right volume female,* ***LVF****= Left volume female*

Table 5 The mean volume of the right and left nasal cavity in males 16.45±0.42cm^3 and 15.00±0.38cm^3, p = 0.010, it is statistically significant (p value <0.05), therefore the right volume of the nasal cavity is bigger than the left in males. RVF 15.34±0.34cm^3, LVF 14.10±0.32cm^3, right volume of the nasal cavity in females is bigger than the left and it is statistically significant, p=0.000, (p value<0.05). However there is no significant difference between the RVF and RVM; LVF and LVM, p= 0.292 and 0.060 respectively.

Table 6

AVERAGE VOLUME(cm^3) FOR NASAL CAVITY	Means ±SEM
MALES	15.98±0.40
FEMALES	14.73±0.34
Overall Average volume for the population	15.35±0.37

Table 6 shows that the mean volume of the nasal cavity in males is 15.98±0.40cm^3, females 14.73±0.34cm^3, p=0.008. Therefore the nasal cavity volume for male is bigger than the nasal cavity volume for females and it is statistically significant.

GRADING SYSTEM PROVIDED FROM THIS PRESENT STUDY

%	Grade
0-25	I
26-50	II
51-75	III
>76	IV

Individuals with Grade I and II are likely to have mild to moderate forms of nasal obstruction/other nasal of symptoms, whereas those with grade III and IV are likely to have severe forms of nasal obstruction.

Table 7: Inferior Turbinate/ Nasal Cavity Ratio

%	male right (frequency)	male left (frequency)	female right (frequency)	female left (frequency)
0-25 (Grade I)	110	111	122	121
26-50 (Grade II)	6	4	6	8
51-75 (Grade III)	0	2	1	1
>76 (Grade IV)	2	1	2	1

DISCUSSION

Volume of the Inferior Turbinate

This present study found out that the mean volume of the inferior turbinate for males was 2.01±0.12, female was 2.22±0.14 and for the entire population it was 2.12±0.13, p=0.102. There was no statistically significant difference between the volume of the inferior turbinate in males and females (p>0.05). Shety *et al*., 2022 in their study on the association between the inferior nasal turbinate volume and the maxillary sinus mucosal lining using cone beam tomography reported their findings which stated that gender had no significant effect on the total turbinate volume. This present study also reported similar findings. Another research done by Uzun, *et al.*, 2004, using CT reported that there were no significant age-related linear dimensional changes in inferior turbinate hypertrophy (ITH). Similarly, no gender-related variation was seen in a study conducted by de Bonnecaze *et al.*, 2018 while evaluating three-dimensional polymorphism of the inferior turbinates, this is similar to this present study. El-Anwar *et al*., (2017) carried out a study on Computed Tomography Measurement of Inferior Turbinate (IT) in Asymptomatic Egyptian Adult and reported that the turbinate length, on the right side ranged from 47.3 to 57.3 mm with a mean of 52.2 ± 3.4 mm, on left side, length of the IT ranged from 44.3 to 59.9 mm with a mean of 51.6 ± 4.1 mm. There was no significant statistical difference in length of both sides ($t = 0.5597$, $p = 0.5781$). This is similar to result from this present study, there was no difference between the right and left length of the inferior turbinate for both males and females.

Volume of the Nasal Cavity

Previous researchers used stereological method (Emirzeogu *et al.*, 2012) to estimate the volume of the nasal cavity. Also Zheng *et al*., 2000 used the acoustic rhinometric method to estimate the volume of the nasal cavity. Schriever *et al*., 2013 reported the average volume of the nasal cavity as 15 -16cm^3 (using Magnetic resonance imaging). In this study, CT was used and measurements were taken at well defined anatomical landmarks and the average volume of the nasal cavity for male and female were 15.98±0.40 cm^3 and 14.73±0.34 cm^3, respectively, whereas the average for the population was 15.35±0.37 cm^3, which was similar to the mean volume reported by Schriever *et al*., 2013 who used Magnetic resonance imaging. To the best of our knowledge, this is the first research that used this method (CT scan with well defined anatomical landmarks) in estimating the volume of the nasal cavity, therefore it is a novel finding. CT scan is more affordable compared to Magnetic resonance imaging in our environment.

Grading of Inferior Turbinate Size

Several attempts have been made by different researchers as regards grading of the inferior turbinate hypertrophy, three of them are based on clinical examination of the inferior turbinate size, while one is based on computed tomography scan imaging and polysomnogram (Leitzen, *et al*., 2014;). Camacho *et al*., 2015, however reported there is no agreed or standardization on the ideal classification system, and this creates difficulty and confusion in assessing effectiveness of any given technique for surgical reduction of inferior turbinate hypertrophy (Abdullah and Singh, 2021). Friedman *et al*., 1999 used the three-grading system; grade 1 is mild enlargement with no obvious obstruction, grade 2 is incomplete obstruction, and grade 3 complete occlusion of the nasal cavity. A study correlating the nasal anatomy to the severity of obstructive sleep apnea classified inferior turbinate hypertrophy as 0 (normal), 1 (mild), 2 (moderate), or 3 (severe) (Leitzen, *et al*., 2014). Camacho *et al*., 2015, classified the inferior turbinate's size as four grades based on its position in the total nasal airway space as visualized on nasoendoscopic assessment. When the inferior turbinate occupies 0 to 25% of total airway space, it is grade 1, grade 2 is 26% to 50%, grade 3 is 51% to 75%, and grade 4 is 76% to 100%. By studying the inferior turbinate bone using computed tomography, Uzun *et al*., 2004, rated the inferior turbinate size as type 1 (lamellar), type 2 (compact bone), type 3 (combined), and type 4 (bullous).

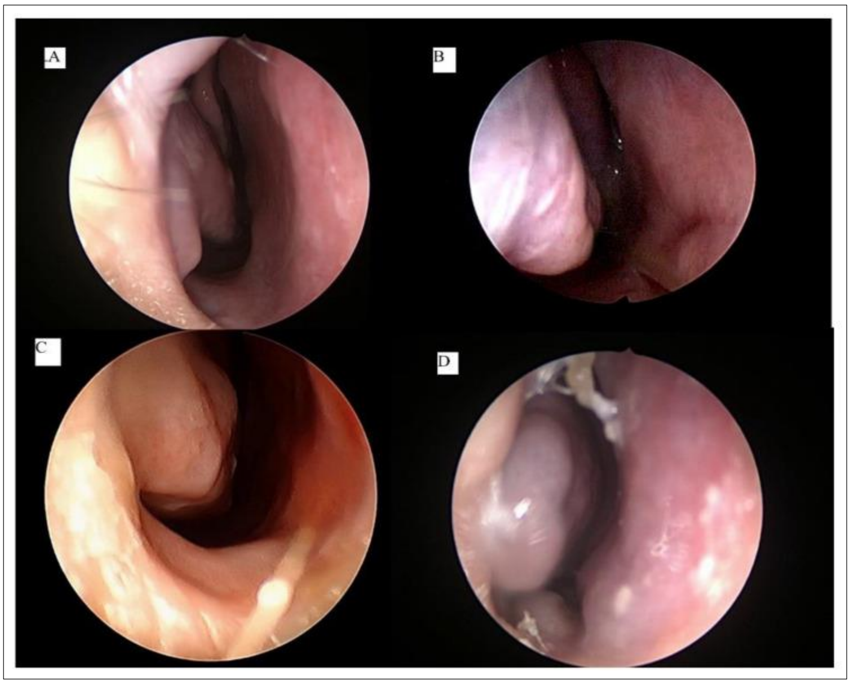

Fig. 6: Nasoendoscopic grading system of inferior turbinate hypertrophy; grade 1 is 0–25% of total airway space occupied (A), grade 2 is 26–50% occupied (B), grade 3 is 51–75% occupied (C), and grade 4 is 76–100% occupied (D). (Abdullah and Singh, 2021)

Novel Report on Grading of Inferior Turbinate: (Inferior Turbinate/ Nasal Cavity Ratio)

This study developed an objective method of grading the inferior turbinate size, it was done by calculating the volume of the inferior turbinate that occupies the nasal cavity; inferior turbinate/nasal cavity multiplied by 100. To the best of our knowledge, this is the first study that used this method to grade inferior turbinate hypertrophy, it is a novel finding. This can be used in predicting the degree of nasal obstruction and severity of symptoms. Individuals with Grade I and II are likely to have mild to moderate forms of nasal obstruction as well as mild to moderate forms of other nasal symptoms, whereas those with Grade III and IV are likely to have severe forms of nasal obstruction/other nasal symptoms.

CONCLUSION

To the best of our knowledge, this is the first research that used this method (well defined anatomical landmarks) in estimating the volume of the nasal cavity and also grading of inferior turbinate size. This study provided a clinically objective tool in assessing the degree of nasal obstruction by providing a grading system for the inferior turbinate/nasal cavity. This tool will particularly be very useful in resource poor settings like ours where nasal endoscopy and rhinometry may not be readily available and affordable. Therefore radiologist can use this grading system to grade the degree of inferior turbinate hypertrophy and predict the degree of nasal obstruction and severity of symptoms.

Recommendation

To ascertain the validity of the novel findings in this study, further researches should be done using this method for comparison.

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