Analysis of the olfactory Fossa on Computed Tomography of the Paranasal Sinuses to Determine Its Anatomical Variation

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Abstract

Background: The morphology of paranasal sinuses is receiving significant attention due to the emergence of functional endoscopic sinus surgery (FESS) & multi-detector computed tomography (CT) scans. **Aim:** The objective of this research is to assess the anatomical diversity of the OF using Keros categorization on computed tomography scans of the paranasal sinuses. **Patients and methods:** This retrospective research has been performed on 200 cases of both genders who had undergone non-enhanced paranasal sinus CTs. The images of those cases that had been directed by the otolaryngology clinic were evaluated retrospectively by a radiologist who had done neck and head radiology. **Results:** A statistically insignificant relation was observed among the Keros classifications regarding sex and age. According to olfactory fossa (OF) depth, a statistically significant relation was detected among sexes and sides regarding the olfactory fossa. A statistically insignificant relation was observed between sex and Keros classification regarding side. **Conclusion:** Performing a computed tomography of the paranasal sinus prior to surgery is beneficial to verify that the operating approach is adequately planned & to assess the structure of the anterior skull base. Using the Keros categorization in paranasal sinus computed tomography reporting might effectively reduce surgical difficulties by providing valuable contributions to the anatomical parts of this region, which are crucial for surgical procedures.

Key words: Keros classification, Olfactory Fossa, paranasal sinuses.

Introduction:

The morphology of paranasal sinuses has gained significant interest due to the emergence of multi-detector computed tomography scan imaging and functional endoscopic sinus operation **(1)**.

It is important to recognize and celebrate commonly occurring anatomical variations to reduce surgical risks **(2)**. The integration of computed tomography with nasal endoscopy yields the most accurate information. Endoscopic sinus operations, like any other surgical procedure, can entail both minor and serious problems. The latter, however uncommon, manifests in around 1.5 percent of such surgical procedures **(3)**. They involve many types of eye injuries, such as damage to the muscles surrounding the eye, herniation of orbital fat, injury to the optic nerve, dysfunction in eye movement, and periorbital emphysema or hematoma. Additionally, there can be leakage of cerebrospinal fluid and damage to the blood vessels or brain within the skull. **(4)**.

Out of several endoscopic sinus operations, ethmoidectomy is frequently associated with difficulties. The assessment of the ethmoidal roof plays a crucial role in minimizing the consequences of an endoscopic operation **(5)**.

The lateral lamella of the cribriform plate of the fovea ethmoidal & the ethmoid bone are the most susceptible parts of the base of skull, as they are prone to iatrogenic injuries throughout operations of functional endoscopic sinus. The olfactory fossa exhibits variation in its structure across several ethnic groups **(6)**.

Hence, it is crucial to possess knowledge about the predominant kind of OF in a specific geographical area and ethnic group, as well as its anatomical characteristics and symmetry. Previous research of this nature hasn't been done in our country. The incidence of Type-one, according to Keros categorization, is 29.8 percent, Type-two is 48.7 percent, & Type-three is 21.4 percent **(7, 8)**.

The purpose of this research was to detect the anatomical variation of the OF by Keros categorization on CT of paranasal sinuses.

Patients and methods:

This retrospective research has been performed on 200 cases of both genders who had undergone non-enhanced paranasal sinus CTs. A radiologist with expertise in neck & head radiology retrospectively assessed the pictures of cases referred by the otolaryngology clinic.

Inclusion criteria: cases of both genders, aged eighteen to sixty-five, underwent a non-enhanced paranasal sinus CT scan to evaluate any paranasal sinus pathology.

Exclusion Criteria: Patients who have undergone prior operation or trauma on the base of the skull or paranasal sinuses, sinus malignancies, PNS neoplastic lesions, PNS fractures or traumas, congenital facial deformities, sinonasal polyposis, and bone-destroying infections are at risk.

Methods:

All patients were imaged by a forty-slice CT scanner manufactured by Siemens called SOMATOM Sensation 40. The computed tomography scan was performed using the following parameters: 120 kilovolts for the detector voltage, three hundred milliamperes per second for the tube current, one second for the rotation time, two millimeters for the section thickness, & a field of view (FOV) of fifteen millimeters. The computed tomography scans have been rebuilt and investigated utilizing the INFINITT 3.0.11.4 (BN11) program, which is image communication and archiving system (PACS) software. The maximum depth of the olfactory fossa was detected by measuring the distance from the uppermost sections of the maxillary sinuses in direct coronal scan pictures. Vertical lines have been extended from this line to reach the lower & upper boundaries of the lateral lamella. The depth of the OF was determined by lowering the measurement of one line from the measurement of a different line. The olfactory fossae were classified according to Keros' categorization, with a depth of one to three millimeters labelled as Type I, four to seven millimeters as Type II, and eight to sixteen millimeters as Type three **(9)**. The precise measurement has been rounded to the nearest number in millimeters.

Statistical analysis of the data: The IBM SPSS software program version 20.0 was utilized to analyze the information that was inputted into the computer. (Armonk, NY: IBM Corp.) Numbers and percentages have been utilized to characterize qualitative information. The normality of the distribution was confirmed utilizing the Kolmogorov-Smirnov test. Range (maximum and minimum), interquartile range (IQR), standard deviation, median, and mean have been used to describe quantitative information. The results were assessed at the five percent level of significance. The tests that have been carried out include: The chi-square test is utilized to compare categorical variables among distinct groups. When the expected count of over twenty percent of the cells is lower than five, the chi-square test is corrected using Fisher's exact or Monte Carlo. Student t-test: A statistical test that is utilized to compare two groups of quantitative variables that are normally distributed. Paired t-test: A statistical test that is used to compare two periods of normally distributed quantitative variables. Mann-Whitney test: A statistical test that is utilized to compare two groups of quantitative variables that are abnormally distributed. Wilcoxon signed a rank test: To compare two periods of quantitative variables that are abnormally distributed

Results:

Table (1): Distribution of demographic data in the studied patients by Keros Classification.

Keros Classification	Studied patients N=200			
	I N=52	II N=104	III N=44	P-value
Sex				
Male	28(53.8%)	64(61.5%)	20(45.5%)	0.18
Female	24(46.2%)	40(38.5%)	24(54.5%)	
Age				
18-40 years	44(42.3%)	70(67.3%)	30(68.2%)	0.06
41-65 years	8(57.7%)	34(32.7%)	14(31.8%)	

P value >0.05: Not significant, P value <0.05 is statistically significant, p<0.001 is highly significant., SD: standard deviation,

According to general characteristics table 1 demonstrations that, there statistically insignificant relation was detected among Keros Classification regarding age and gender.

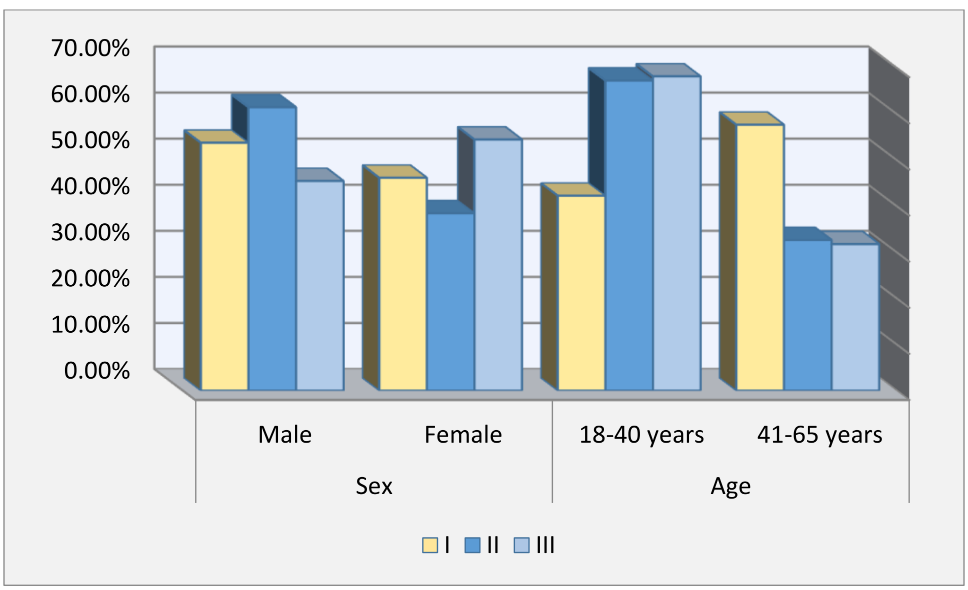

Figure (1): shows distribution of demographic data in the studied patients by Keros Classification.

Table (2): Distribution of depth according to sex and side.

	Studied patients N=200		
	Male	**Female**	**P-value**
Right (mm)	4.6±1.3	4.2±1.3	0.03
Left (mm)	1.6±1.4	4.57±4.1	<0.001

According to olfactory fossa (OF) depth, table 2 demonstrations that, there statistically significant relation was observed among sex and side regarding olfactory fossa.

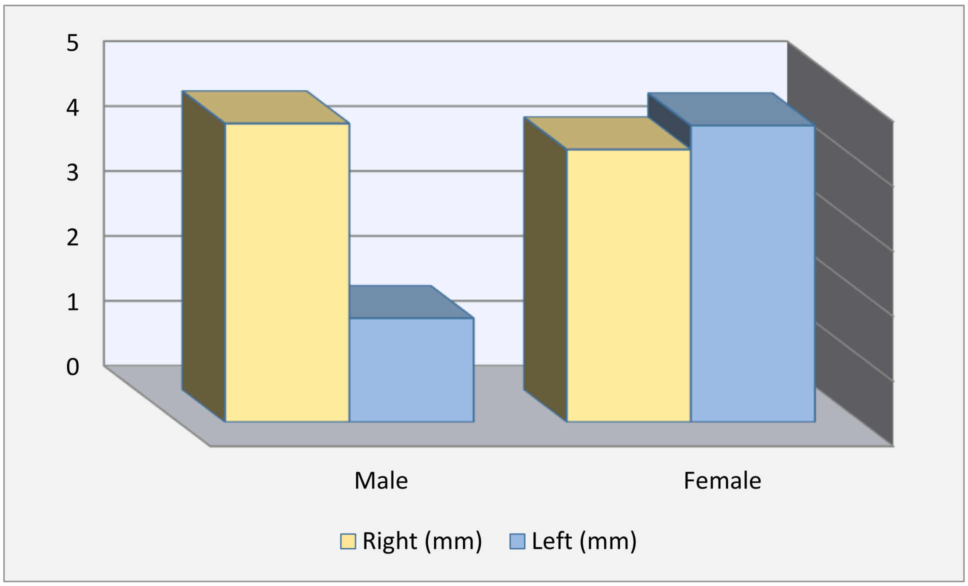

Figure (2): shows distribution of depth according to gender and side.

Table (3): Distribution of olfactory fossa according to the Keros categorization & side.

Keros Classification	**Studied patients N=200**			
	I N=52	**II** N=104	**III** N=44	**P-value**
Side				
Right	26 (50%)	53 (50.9%)	21 (47.7%)	0.93
Left	26 (50%)	51 (49.1%)	23 (52.3 %)	

According to olfactory fossa, table 3 show that, there statistically insignificant relation was observed among sex and Keros Classification regarding side.

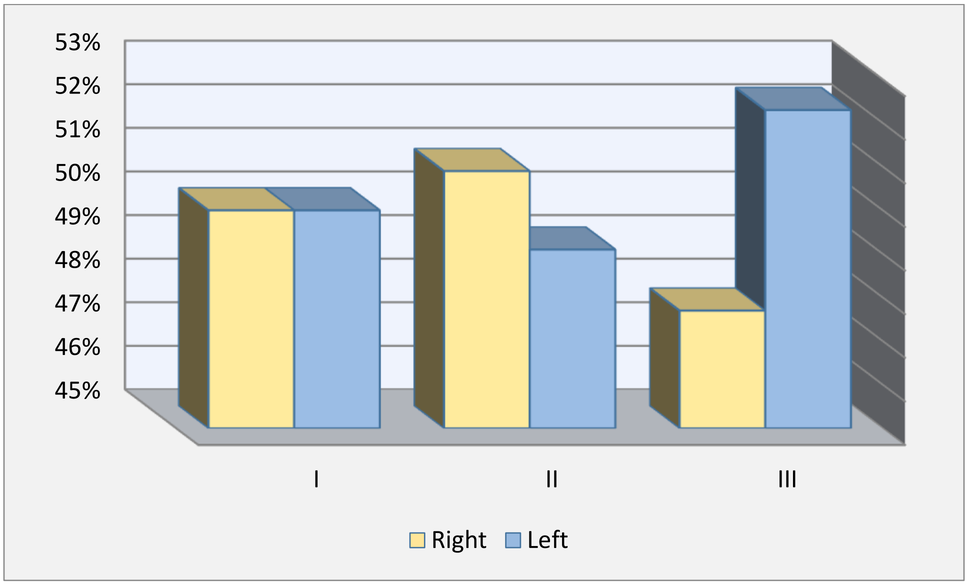

Figure (3): shows distribution of according to the Keros classification and side.

Discussion:

FESS is now widely accepted as the preferred therapy for nasal and paranasal sinus disorders. The computed tomography scan of the paranasal sinus (PNS) is a crucial diagnostic tool for evaluating the sinuses and providing surgical advice to the surgeon. Multiplanar imaging, specifically coronal reformations, provides specific information on the anatomical structure and variability of the paranasal sinuses. **(10)**.

The anterior skull base houses the OF, the anterior cranial cavity has a depression known as the cribriform plate of the ethmoid, which is limited medially by the perpendicular plate of the ethmoid & laterally by the lateral lamella. The olfactory fossa's depth and lateral lamella's height have traditionally been attributed to this area's susceptibility to injuries in trans-nasal endoscopic surgery **(11)**.

Injury to the base of the skull is a major surgical complication of sino-nasal surgeries, and the potential outcomes of this procedure include damage to the optic nerve, leakage of cerebrospinal fluid, inflammation of the meninges, injury to the carotid blood vessels, orbital hematoma, and stenosis of the nasolacrimal duct. **(12)**.

The Keros classification was described in 1962 by Predrag Keros (1933–2018), a Croatian physician. Based on its depth, it classifies the OF anatomy into three: type I (one to three millimeters), the cribriform plate, and the ethmoid roof, which are almost in the same plain. For type II (four to seven millimeters) and type III (eight to sixteen millimeters), the lateral lamella is greater & the OF is deeper. Type three is considered a dangerous ethmoid and possesses a higher risk of injury throughout endoscopic sinus surgeries (ESS) **(5)**.

In the assessment of CT- scans of the PNS before ESS, the key points to be evaluated include the extent of the density of the sinuses and their drainage pathways, critical anatomic variants, &' the condition of the soft tissues of the orbits, skull base/brain, & neck **(13)**.

The major results of this investigation were as follows:

In the current study, we found that, according to demographic data, a statistically insignificant relation was detected among the Keros classifications regarding sex and age.

Consistent with our findings, **Karatay E et al. (14)** conducted a retrospective analysis of paranasal sinus computed tomography to identify the frequency of Keros types and assess the depth of the OF in our community using the Keros categorization. They discovered that 282 cases (54.02 percent) have been men, and 240 cases (45.98 percent) have been women, out of the 522 cases involved in the investigation. The average age of the cases was 38.17±14.12 years in total, 39.01±14.85 years for women, and 37.46±13.45 years for men. The youngest case in both genders was eighteen years old, while the oldest case in males was seventy-eight years old and eighty-seven years old in women. Keros types weren't statistically significant when contrasted among both sexes and sides ($p > 0.05$).

Additionally, our discoveries agreed with those of **Shahid M et al. (15)**, who aimed to detect the incidence of anatomical difference in the OF between the adult population through Keros categorization on CT of paranasal sinuses. The investigation comprised sixty-five cases, ranging in age from eighteen to sixty-five years, according to their report. The average age was 33.09 ± 10.86 years. The research population consisted of forty-seven cases (72.3 percent) among the ages of eighteen to forty and eighteen cases (27.7%) among the ages of forty-one and sixty-five. Of the sixty-five cases, thirty-six (55.4 percent) have been male and twenty-nine (44.6 percent) have been women. Gender and age didn't exhibit a significant association (p-value 0.559) with differences in the anatomy of the olfactory fossa.

Contrary to our findings, **Dessi P et al. (16)** demonstrated that the Keros Type-two OF was more commonly observed in male than in females ($p<0.001$). Additionally, **Elwany S et al. (17)** demonstrated that males were more likely to have a Type II olfactory fossa. Females were more commonly diagnosed with Keros Type-I.

Our research demonstrated a statistically significant correlation among sex and side regarding the profundity of the olfactory fossa (OF).

Karatay E et al. (14) discovered that the average depth of the 1044 OF investigated was 4.89 millimeters, with a SD of 2.79, which is consistent with our findings. The average depth of the OF on the right side was 4.86 millimeters, while the average depth on the left side was 4.91 millimeters. A statistically significant distinction in mean olfactory fossa depth was observed among females and males ($p<0.001$). Nevertheless, a statistically insignificant distinction was observed when the mean right of depth has been contrasted based on gender ($p > 0.05$). In the same vein, a statistically insignificant distinction was observed ($p > 0.05$) when the mean depths of the right and left olfactory fossa have been compared for all cases. Nevertheless, there was statistical significance ($p<0.001$) when the mean left OF depth was compared by sex.

Shahid M. et al. (15) additionally stated that the mean computed tomography depth of the OF in their research was 6.34 ± 4.03 millimeters. **Erdem G et al. (10)** also demonstrated almost identical results, with an olfactory fossa depth of 6.1 ± 2.2 millimeters.

In contrast to our findings, **Shrestha R et al. (18)** conducted a retrospective evaluation of the depth of the olfactory fossa and analyzed paranasal sinus computed tomography to identify the occurrence and categorization of various Keros types in our population. They reported that the mean olfactory fossa depth on the right side was 4.4±1.44 millimeters, while on the left side it was 4.5±1.5 millimeters. In comparison to men, the mean olfactory fossa depth in females on the right side was slightly lower (4.3±1.48 millimeters versus 4.5±1.41 millimeters), while it was slightly higher on the left (4.5±1.53 millimeters versus 4.4±1.49 millimeters). A statistically insignificant distinction among the right and left was observed.

In the present investigation, there was a statistically insignificant association among sex and Keros classification regarding the olfactory fossa with respect to the side.

Karatay E et al. (14) found that the distribution of OF was based on the side and Keros categorization. Type one was present in 322 (30.85 percent), type two in 697 (66.75 percent), and type three in twenty-five (2.4 percent) of the 1044 OF. This finding is consistent with our findings.

Type two is the most prevalent on both the left and right sides, as well as in both genders, according to this data. In the right-sided olfactory fossa, there were 160 Keros type one (30.7 percent), 350 type two (67.0%), and twelve type three (2.3%) subjects. There were 162 Keros type 1 (31.0%), 347 type two (66.5%), and thirteen type three (2.5%) subjects in the left-side total.

Additionally, our discoveries agreed with those of **Shrestha R et al. (18)**, who reported that each computed tomography has been counted as two cases (left & right) for a total of 508 cases. Eighty-two cases (16.1%) have been Keros one on both sides (left and right), 373 (73.4 percent) were Keros II, and fifty-three (10.5 percent) were Keros III. Thirty-eight females (18.5 percent) have been categorized as Keros one, 145 (70.4 percent) as Keros two, & twenty-three females (11.1 percent) as Keros three. Keros I was assigned to forty-four males (14.6%), Keros II to 228 (75.5 percent), and Keros III to thirty (9.9 percent). Different Keros types were observed bilaterally in sixty-eight subjects (26.8 percent). There was an was an insignificant association detected among gender and side in the categorization of Keros into types I, II, and III (p-value > 0.05 in all categories).

Conclusion:

The Keros classification plays a crucial role in objectively assessing the anatomy of the anterior skull base & guiding the surgeon in performing a safe treatment, particularly in functional endoscopic sinus operation. Performing a pre-surgery computed tomography of the paranasal sinus is beneficial to verify that the operating approach is adequately planned and to evaluate the structure of the anterior skull base. Implementing the Keros categorization in paranasal sinus computed tomography reporting might effectively reduce surgical difficulties by providing valuable contributions to the anatomical structures in this region, which are crucial for operations.

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Conflict of Interest: Nil

References:

1. Verma J, Tyagi S, Srivastava M, Agarwal A. Computed tomography of paranasal sinuses for early and proper diagnosis of nasal and sinus pathology. Int J Otorhinolaryngol Head Neck Surg. 2016 Apr;2(2):70.
2. Salroo I, Dar NH, Yousuf A, Lone KS. Computerised tomographic profile of ethmoid roof on basis of keros classification among ethnic Kashmiri's. Int J Otorhinolaryngol Head Neck Surg. 2016 Jan 7;2(1):1-5.
3. Chaaban MR, Rana N, Baillargeon J, Baillargeon G, Resto V, Kuo YF. Outcomes and complications of balloon

and conventional functional endoscopic sinus surgery. American journal of rhinology & allergy. 2018 Sep;32(5):388-96.

4. Seredyka-Burduk M, Burduk PK, Wierzchowska M, Kaluzny B, Malukiewicz G. Complicações oftálmicas da cirurgia endoscópica dos seios nasais☆. Brazilian Journal of Otorhinolaryngology. 2017 May; 83:318-23.
5. Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. Zeitschrift fur Laryngologie, Rhinologie, Otologie und ihre Grenzgebiete. 1962 Nov 1;41:809-13.
6. Pawar A, Konde S, Bhole P. Assessment of depth of olfactory fossa in pre-functional endoscopic sinus surgery computed tomography scan of paranasal sinuses. Int J Otorhinolaryngol Head Neck Surg. 2017 Dec 22;4(1):83.
7. Babu AC, Nair MR, Kuriakose AM. Olfactory fossa depth: CT analysis of 1200 patients. Indian Journal of Radiology and Imaging. 2018 Oct;28(04):395-400.
8. Jacob TG, Kaul JM. Morphology of the olfactory fossa–A new look. journal of the anatomical society of india. 2014 Jun 1;63(1):30-5.
9. Rahman AS, Hwang PH, Alapati R, Lin Y, Nayak JV, Patel ZM, Yan CH. Indications and outcomes for patients with limited symptoms undergoing endoscopic sinus surgery. American Journal of Rhinology & Allergy. 2020 Jul;34(4):502-7.
10. Erdem G, Erdem T, Miman MC, Ozturan O. A radiological anatomic study of the cribriform plate compared with constant structures. Rhinology. 2004 Dec 1;42(4):225-9.
11. Hamour AF, Kus L, Monteiro E, Scheffler P, Lee J, Vescan A. Radiological Anatomy of the Olfactory Fossa: Is Skull Base Anatomy Really Ever “Safe”?. Journal of Neurological Surgery Part B: Skull Base. 2022 Feb;83(01):053-8.
12. Fokkens WJ, Lund VI, Mullol J, Bachert C, Alobid I, Baroody F, Cohen N, Cervin A, Douglas R, Gevaert P, Georgalas C. European position paper on rhinosinusitis and nasal polyps 2012. Rhinology. 2012;50(suppl. 23):1-298.
13. Hoang JK, Eastwood JD, Tebbit CL, Glastonbury CM. Multiplanar sinus CT: a systematic approach to imaging before functional endoscopic sinus surgery. American journal of roentgenology. 2010 Jun;194(6):W527-36.
14. Karatay E, Avcı H. Evaluation of Olfactory Fossa Anatomy by Computed Tomography and the Place of Keros Classification in Functional Endoscopic Sinus Surgery. Southern Clinics of Istanbul Eurasia. 2021 Mar 1;32(1).
15. Shahid M, Mahmood R, Ullah H, Sheraz MA, Ibrahim MI, Ali FZ. Anatomical Variation of Olfactory Fossa on Computed Tomography of Paranasal Sinuses. Pakistan Armed Forces Medical Journal. 2023 Feb 28;73(1):239-42.
16. Dessi P, Castro F, Triglia JM, Zanaret M, Cannoni M. Major complications of sinus surgery: a review of 1192

procedures. The journal of laryngology & otology. 1994 Mar;108(3):212-5.

17. Elwany S, Medanni A, Eid M, Aly A, El-Daly A, Ammar SR. Radiological observations on the olfactory fossa and ethmoid roof. The Journal of Laryngology & Otology. 2010 Dec;124(12):1251-6.

18. Shrestha R, Gautam M, Shrestha N. Evaluation of Olfactory Fossa Depth Using Computed Tomography in A Tertiary Center: A Retrospective Study. Nepalese Journal of Radiology. 2023 Jun 30;13(1):4-8.