ORIGINAL ARTICLE

Prevalence of Olfactory Fossa Variants and Their Association with Age and Gender: A CT-Based Observational Study using Keros Classification

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ABSTRACT

Objective: To determine the prevalence of olfactory fossa variants based on Keros classification and to assess their association with age and gender using computed tomography.

Study Design: Retrospective observational study.

Place and Duration of Study: This study was conducted at the Department of Radiology, Pakistan Ordinance Factory (POF) Hospital, Wah Cantt, Pakistan from January 2022 to January 2024.

Methods: Patients of either gender above 10 years were included in the study who had undergone CT PNS. A qualified radiologist measured the olfactory fossa depth using reference landmarks. Both descriptive and inferential statistical techniques were utilized in the examination of the Keros type distribution among the patients. Inferential statistics, particularly chi-square tests, were employed to examine the relationships between categorical variables such as gender and age groups and the distribution of Keros types. *P*-values were used to assess the statistical significance of these correlations.

Results: A Total of 123 patients were included in the study, including 69 females (56.1%) and 54 males (43.9%). Minimum age was 10 year and maximum age was 87 years. The results show type II Keros fossa is the most prevalent type, followed by type I, while type III is rare. A symmetrical olfactory fossa is more common than asymmetrical. Age groups and Keros Type on both sides do not significantly correlate, according to the chi-square test.

Conclusion: Chronic sinusitis and nasal polyps are prevalent conditions, and their treatment has been transformed with the advent of advanced surgical procedures, notably Functional Endoscopic Sinus Surgery. The depth of the olfactory fossa varies, making the Keros classification particularly important because it assesses the variations in olfactory fossa depth and symmetry, which is important for surgeons to avoid iatrogenic injuries.

Keywords: *Cribriform Plate, Keros Calssification, Olfactory Fossa.*

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Introduction

Nasal polyps and chronic sinus disease are prevalent diseases encountered by otolaryngologists. Their treatment has been revolutionised with the introduction of functional endoscopic sinus surgery (FESS).[1] FESS is a surgical technique used for the management of chronic rhinosinusitis that helps to restore normal sinus functioning with minimal discomfort to the patients.[2] To perform successful endoscopic sinus surgeries, one must be aware of the endoscopic anatomy of the nose and especially about the olfactory fossa region so that complications such as cerebrospinal fluid leaks and anterior ethmoidal artery injuries can be avoided.[3]

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Olfactory fossa is a section of the skull base situated in the anterior cranial fossa that houses important structures like the olfactory bulbs, olfactory tracts, and olfactory nerves.[3]

Height of lateral lamella of cribriform plate is of great significance as it determines the depth of olfactory fossa.[4] The depth of the olfactory fossa varies, and Keros classification is highly relevant as it focuses on the lateral lamella height, which is the distance between the cribriform plate and the roof of the ethmoid. This measurement categorizes the olfactory fossa into three types. Type I (1 to 3 mm) is deemed the safest as it represents the shallowest depth. Type II (4 to 7 mm) is generally acceptable in terms of safety. Type III (8 to 16 mm) is risky because of the significantly greater distance between the ethmoid roof and the cribriform plate. Increased cribriform plate depth correlates with heightened risks of complications during endoscopic sinus surgery.[5]

Preoperative imaging of all patients must be done beforehand for proper identification of the variable anatomy of the ethmoidal roof. A CT scan allows excellent visualisation of all bony details.[6]

As various reports have shown the variable anatomy of the ethmoidal roof in various ethnic populations, the purpose of our study was to assess the depth of the olfactory fossa in the people of Wah Cantt, Pakistan, as previously this study was not conducted in this area.[6]

The objective of the study is to determine the prevalence of olfactory fossa variants based on Keros classification and to assess their association with age and gender using computed tomography in patients presenting in POF hospital, Wah Cantt.

Methods

The retrospective observational study was conducted at the Department of Radiology, Pakistan Ordinance Factory (POF) Hospital, Wah Cantt, Pakistan from January 2022 to January 2024 after taking approval from the Ethical Review Committee of the hospital vide letter no: ERC/16/2021, dated: 10th December 2021. The study evaluated patients aged 10 years and older who had undergone non-contrast CT paranasal sinuses (PNS) from January 2022 to January 2024. Patients with a history of trauma, surgery, facial congenital anomalies, or tumors were not included in the study.

Images were obtained using a Toshiba 16-slice Multi Detector CT scanner. Scanning was performed with patients in the supine position. The technical parameters for image acquisition included tube voltage of 120 kV, an effective mAs of 100, a rotation time of 0.75 seconds, a slice thickness of 3 mm, and a Field of View of 15 cm. Picture Archiving and Communication System software is used, focusing exclusively on coronal sections in the bone window.

The anatomical points were identified and used for measuring olfactory fossa depth as shown in Figure 1.

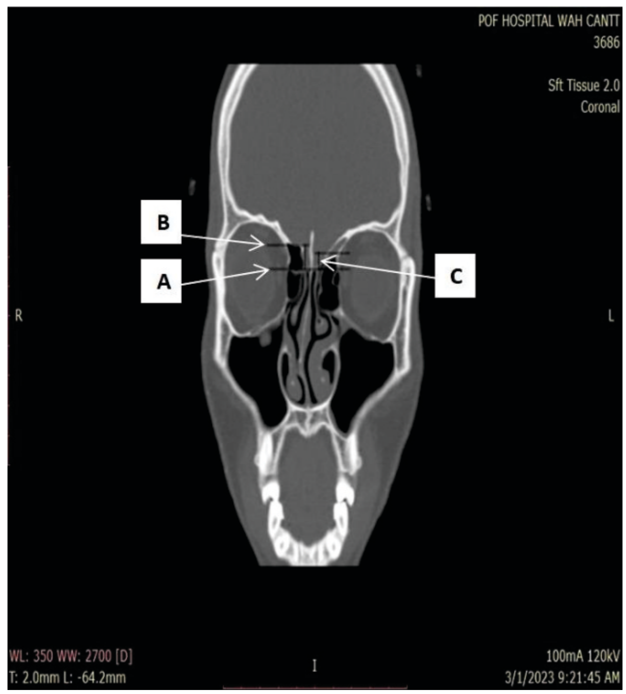

Fig.1: Line A: Horizontal line drawn at the level of cribriform plates
Line B: Horizontal line drawn along the fovea ethmoidalis
Line C: Vertical line drawn using distance measuring tool connecting line, A to line B, which is equal to the height of the lateral lamella of the cribriform plate that reflects the olfactory fossa depth

The heights of the right and left lateral lamellae were measured separately by a single experienced radiologist. The radiologist was not blinded to patient demographics or study objectives, which may introduce bias. However, measurements were consistently performed by a single experienced radiologist using standardized landmarks, reducing interobserver variability. Formal interobserver or interobserver agreement analysis (e.g., Kappa statistics) was not conducted and is acknowledged as a study limitation. Olfactory fossa depths were classified as Keros type I for 1–3 mm, type II for 4–7 mm, and type III for ≥8 mm.[5] The measured values are rounded off to the nearest whole number.

The data was entered and analyzed using SPSS software version 23. Both descriptive and inferential statistical techniques were utilized in the examination of the Keros type distribution among the patients. Inferential statistics, particularly chi-square tests, were employed to examine the relationships between categorical variables such as gender and age groups and the distribution of Keros types. *P*-values were used to assess the statistical significance of these correlations. A comprehensive understanding of the distribution and possible demographic effects on the prevalence of various Keros types has been made possible by these techniques.

Results

A total of 123 patients were included in the study, including 69 males (56.1%) and 54 females (43.9%). Minimum age was 10 years and maximum age was 87 years. The incidence of Keros types by laterality (right and left sides) and gender was summarized and presented using descriptive statistics, as shown by the computation of frequencies and percentages in Figure 2 and Table 1.

Figure 2 indicates that type I occurs on both sides equally (43.09%), for an overall presence of 86.18%. With a higher frequency on the right side (55.28%) than the left (53.66%), Type II is most common type and accounts for 108.94% of the total. The incidence of Type III is low, occurring in 1.63% of cases on the right and 3.25% on the left, for a total of 4.88%. While type III is still rare, this distribution suggests a balance between types I and II, with a slightly higher prevalence on the right side for type II.

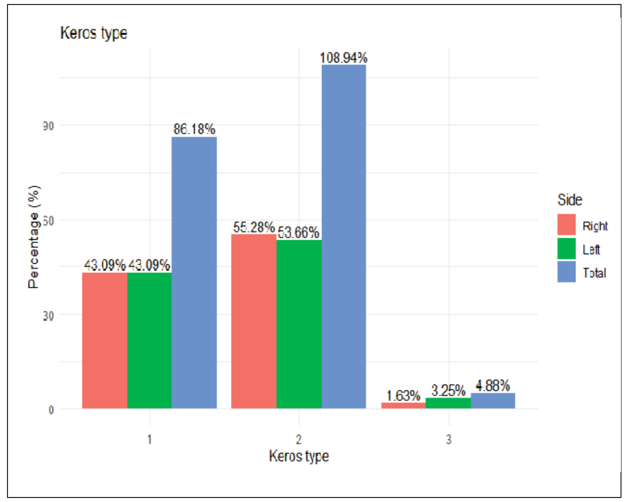

Fig.2: Percentage distribution of Keros types and laterality

The distribution of Keros types by gender (M = Male, F = Female) and sides (Right and Left) is shown in Table 1. In Keros type I, the counts of the males are 28 on the right and 29 on the left, and the counts of the females are 25 on the right and 24 on the left. In contrast to males, who have 25 on the right and 38 on the left, Type II has a greater count in females, with 43 on the right and 28 on the left. With males and females displaying one on the right and two on the left, Type III is noticeably less common. The gender-specific differences in the distribution of Keros types are highlighted by this data, especially for type II. In contrast, types I and III have more evenly distributed distributions across genders and sides.

Table 1: Gender-specific distribution of Keros types across right and left

Keros Type	Right- (M)	Right- (F)	Left- (M)	Left- (F)
I	28	25	29	24
II	25	43	38	28
III	1	1	2	2

Table 2: Frequency and percentage distribution of Keros types

Types	Male	Male (%)	Female	Female (%)
Same type	54	78.26	47	87.04
Asymmetry	15	21.74	7	12.96
Total	69	100	54	100

Table 3: Contingency Table showing the distribution of Keros Type on the left side across various Age Groups, Gender, with *P*-values

Age (Years)	Keros type left side			*Chi-Square* value	*P*- value
	I	II	III		
<40 years	17	25	3		
41-60 years	23	17	0	7.47	0.11
60+ years	13	24	1		
Gender					
Male	29	38	2	0.16	0.92
Female	24	28	2		

Table 4: Contingency Table showing the distribution of Keros Type right side across various Age Groups, Gender with *P*-values

Age (Years)	Keros type right side			*Chi-Square* value	*P*- value
	I	II	III		
<40 years	18	26	1		
41-60 years	23	17	0	6.17	0.19
60+ years	12	25	1		
Gender					
Male	25	43	1	3.15	0.21
Female	28	25	1		

The frequency and percentage distribution of Keros types among individuals, both male and female, are shown in Table 2. Of the male participants, 15 people (21.74%) exhibit asymmetry, whereas 54 individuals (78.26%) have the same Keros type on both their left and right sides. Comparatively, out of the female participants, seven individuals (12.96%) have asymmetry, while 47 individuals (87.04%) have the same Keros type on both sides. This suggests that compared to men, a greater percentage of females have matching Keros types on both sides. On the other hand, males exhibit asymmetry in Keros types more frequently than females. These results point to a gender difference in the distribution of Keros types in this group, with males more likely than females to exhibit asymmetry.

The distribution of Keros Type on the left and right sides for each age group is displayed in the contingency table along with the appropriate *P*-values in Table 3 and 4. Age groups and Keros Type on both sides do not significantly correlate, according to the chi-square test (chi-square (χ^2) = 7.47, *P* = 0.11 on the left side and χ^2 = 6.17 with *P*= 0.19 on the right side). It concludes that there is no significant distinction in the distribution of Keros Type between the age groups classified as <40 years, 41-60 years, and 60+ years. Similarly, the distribution of Keros Type for each gender is shown in the table along with the *P*-values. According to the chi-square test results (χ^2 = 0.16, *P*=0.92 on the left side and χ^2 =3.15, *P*=0.21 on the right side), gender and Keros Type do not significantly correlate. Keros Type is distributed similarly in males and females.

Discussion

Functional endoscopic sinus surgery (FESS) is minimally invasive procedure used now days to restore sinus ventilation and treat chronic sinusitis and other related conditions that are refractory to medications.[7,8]

Pre FESS CT PNS is mandatory because it provides detailed information about normal anatomy and anatomical variants which could affect the surgical procedure. It also provides clear extent of disease process. Thus it helps the surgeon to map out the surgical plan to avoid the complications.[9-11]

It is responsibility of radiologist to identify and document all anatomical variants on pre-operative imaging report. There is a long list of anatomical variants in paranasal sinuses however five variants are crucial and must be evaluated. One most important variant among these is cribriform plate which is part of olfactory fossa.[11,12]

The ideal imaging plane to assess the cribriform plate is the coronal plane, and it is evaluated by documenting keros classification, asymmetrical keros, and skull base dehiscence. Olfactory fossa depth is the height of the lateral lamella. The lateral lamella is a very thin bone and prone to injury during FESS. A longer lateral lamella results in a more inferiorly placed cribriform plate consistent with type III keros, which increases the risk of perioperative complications.[12,13] Asymmetric keros describes the asymmetric level of the ethmoid roof (fovea ethmoidalis) on both sides in the same patient. Asymmetry is also associated with increased risk of perioperative iatrogenic injury.[14]

Our study has shown that 55.28% patients have type II keros on the right and 53.66% on the left, whereas 43.09% patients have type I on both sides and 1.63% patients have type III on the right and 3.25% patients have type III on the left. Thus, the most common type is keros type II, next is type I, and lastly type III, which is the least common in our population. This finding has important clinical implications, especially in the context of FESS. Based on feedback from ENT surgeons in our institution, a patient with Keros type II required heightened intra-operative caution as the lateral lamella in this type is longer than in type I. Our study has also shown that symmetrical olfactory fossa is common (82%) than asymmetrical keros (18%). High prevalence of symmetrical olfactory fossa suggests a low perioperative risk in most patients. Similar results are shown by studies conducted by Naidu L et al. in South Africa, Naaz S et al.in Egypt, and Mahdian M et al.[14-16] In contrast to our study, the study done by Shama AM et al. in Egypt, has shown that keros type I is more common than type II.[17] It supports the hypothesis that different populations have different configurations of the olfactory fossa.[17] Only one study by Babu A. et al. has observed that asymmetric OF is more common than symmetric OF, in contrast to our study.[18]

In our study, keros type II is more common in males on both sides; type I is more prevalent in females on the right side only. Systematic literature review has shown that keros type II is more common in males in both sides and keros type I is more prevalent in females on both sides.[19,20]

In our study, we observed no correlation between keros classification and age groups or gender. Similar results are shown by a study by Gupta P et al. Another survey by Shahid M. et al has also shown that there is no statistically significant correlation between age groups and keros classification.[21,22]

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In our study, we observed no correlation between keros classification and age groups or gender. Similar results are shown by a study by Shahid M et al. Another survey by Lakhani M. et al has also shown that there is no statistically significant correlation between age groups and keros classification.[22]

There are some limitations to our study; a single radiologist assesses all CT scans. The sample size was small, and we included a very limited population at a single center in our study. This may limit the precision and generalizability of the findings, but it provides valuable data in this specific cohort, suggesting the need for larger studies in other regions. Although there is a list of anatomical variants that could significantly affect FESS, we have focused only on olfactory fossa depth and asymmetry in our study.

Conclusion

Our study has evaluated the depth of the olfactory fossa and asymmetry in the height of the lateral lamella on both sides in our population. We have found that type II keros is the most prevalent type, and symmetrical olfactory fossa is common than asymmetrical olfactory fossa. Thus, it would help the surgeons to be aware of one of the most important anterior skull base anatomical variations to avoid iatrogenic injuries.

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Author Contributions

M: Manuscript writing for methodology design and investigation
SJR: Conception and design of the work
RM: Data acquisition, curation, and statistical analysis
AA: Validation of data, interpretation, and write-up of results
FA: Writing the original draft, proofreading, and approval for final submission
TAM: Revising, editing, and supervising for intellectual content