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Original Research Article

Computed Tomographic Findings of the Ethmoid roof by Keros classification in patients attending a Tertiary Hospital in Dar es salaam, Tanzania

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Abstract: ***Background***: The variations of the olfactory fossa/ethmoid roof are common. These variations are important to be acknowledged when dealing with endoscopic sinonasal and skull base surgeries due to possibilities of injuries to the vital structures. The depth of the olfactory fossa is classified as Keros type I, II, or III (Depth 1-3mm, 4-7mm, and 8-16mm, respectively). Keros type III is consider the most venerable type to iatrogenic injury followed by type II. The variations can be similar or dissimilar among countries, geographies, and ethnicities. Functional endoscopic sinus surgery (FESS) is currently the preferred surgical option worldwide when dealing with nasal or sinonasal diseases. Awareness of the anatomical landmarks, Variations in the depth of the olfactory fossa, assist the surgeon in avoiding CSF leaking, brain herniation, and hemorrhage. For a few decades, it was introduced in Africa (Egypt, Nigeria, South Africa, Kenya, etc.). FESS was introduced at the Muhimbili National Hospital, Tanzania in 2010 and is currently becoming widely practiced in the country. Only a single study done in Kenya on anatomical variations of the ethmoid roof was found in east Africa. No data was found in Tanzania and due to the scarcity of data in Africa especially in east Africa, this study was necessary. ***Objective***: This study aimed at determining the ethmoid roof findings on computerized tomography by Keros classification among patients attending MNH services. ***Materials and Methods***: A hospital-based, cross-sectional study was conducted at the Muhimbili national hospital, radiology department for four months, among 351 CT scans obtained from patients aged 12years and above. A convenient sampling method was employed, whereby daily continuous data collection from all head and neck, and PNS CT scans that met criteria done on the corresponding days were included until the required sample was attained. Data collection checklists were used to record the age, sex, sides of the CT scan, the height of the LLCB (olfactory fossa depth), the Keros classification, lateralization, and location of the anterior ethmoid artery about the skull base. ***Results***: A total of 351 CT scans were recruited in this study, of whom 220(62.7%) were from male patients and 131(37.3%) were from female patients with a female to male ratio of 1:1.7. The CT scans studied were from patients aged 12 to 91years, with a median age of 45 (28,61). The most common age groups in this study were 25-44 years and over 60 years (31.6% and 26.8%, respectively). The most prevalent kind of ethmoid roof was Keros type II (64.67%), and type III being the least common (6.24%). Keros type II was the most prevalent in terms of age and sex distribution of patients from whom the CT scans were obtained, followed by Keros type I, the type III being the least. When analyzing the distribution of Keros classification by sides, the same prevalent order was observed. It was also found that among the 351 CT scans, there was 21.7% asymmetry in Keros types between the right and left sides. With

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Keros type III there was a high chance to encounter a low lying anterior ethmoid artery. ***Conclusion***: Type II was the most common Keros type discovered in this study while Keros type III was found to be the least common. Age, gender, and sides did not affect the distribution of olfactory fossae. Asymmetry of ethmoid roofs between the right and left and right among CT scans was observed.

Keywords: "Computed Tomography", "Ethmoid Roof", "Olfactory Fossa", "Anterior Ethmoidal Artery", "Keros Classification", "Functional Endoscopic Sinus Surgery", "Skull Base", "Fovea Ethmoidalis", "Lateral Lamella of the Cribriform Plate", "Endoscopic Sinus Surgery", and "Cerebrospinal Fluid Leak".

INTRODUCTION

Variation of the ethmoid roof which is a thin layer part of the anterior skull base making it more vulnerable to iatrogenic injury during endoscopic sinus surgeries. The computed tomography (CT) scan is the standard method of Sinonasal imaging and radiological evaluation, not only for diagnosing sinonasal diseases but also to assist the surgeon in describing their anatomy for use as a road map during endoscopic procedures [11]. Knowledge of the Sinonasal anatomy of an individual patient before surgery increases vision and awareness for surgeons during operation because the paranasal sinuses are adjacent to the vital structures, including the orbital spaces, the brain, and other associated anatomical variations especially of the ethmoid roof, and, the position of the anterior ethmoidal artery. Endoscopic sinonasal surgery (ESS) is a minimally invasive method developed in Germany in 1960 for nasal polyposis, acute or chronic rhinosinusitis, developmental anomalies, and neoplasms [12, 13]. FESS was first introduced in Tanzania in 2010 at the Muhimbili National Hospital.

Sometimes during the procedure, an endoscope is directed to the fovea ethmoidalis, which is a part of the frontal bone orbital plate. The fovea ethmoidalis forms the roof of the ethmoidal labyrinth that separates ethmoidal cells from the anterior cranial fossa. The lateral lamella of the cribriform plate (LLCP) is attached to the medial side of fovea ethmoidalis (FE). The LLCP is the thinnest and hence most fragile component in the skull base, readily pierced and shattered by ESS, resulting in problems [12-14].

Endoscopic sinus surgery requires knowledge of the anatomical variations of the olfactory fossa (OF) and the course of the anterior ethmoid artery to avoid iatrogenic damage to these vital structures. Individuals with asymmetry in depth between the right and left olfactory fossa may have a greater risk of intracranial penetration during endoscopic sinus surgery. The olfactory fossa is a depression in the anterior cranial cavity where it forms the base of the ethmoid cribriform plate. The cribriform plate's lateral lamella is found in the lateral section of the olfactory fossa, whereas the crista Galli is found in the medial part (figure 1) [15, 16]. The height of the lateral lamella of the cribriform plate determines the depth of the olfactory fossa.

The depth of the olfactory fossa is classified into three types, according to Keros' 1962 classification: type I, 1–3 mm; type II, 4–7 mm; and type III, 8–16 mm. (Fig. A). The most harmful is Type III, which has a very thin cribriform plate. Understanding of these anatomical differences allows surgeons to operate more precisely and with fewer difficulties [14-17].

The anterior ethmoid artery is the vital structure that might be injured during endoscopic sinus surgery.

This blood artery travels from the orbit to the anterior ethmoid cranial fossa via the roof of the ethmoid in a posterolateral to anteromedial orientation. During surgery, inadvertent damage to the AEA causes significant bleeding. If the lateral section of the AEA is retracted into the orbit, retrobulbar haemorrhage can be visible, and if not decompressed quickly, blindness can result. CSF leaking occurs when LLCB is injured [18–22].

METHODS

A cross-sectional study was conducted at MNH, in Tanzania from February to June 2022. MNH is Tanzania's largest teaching and tertiary referral hospital, receiving patients from all of Tanzania's zones, as well as Zanzibar and adjacent countries. It has a bed capacity of 1500 beds, the hospital admits an average of 157 patients per day. It is found in Dar es salaam city that has an estimated population of 7.4 million. Inpatient and outpatient imaging investigations are performed by the radiology department, which receives requests from many disciplines, including otorhinolaryngology. It equipped with modern equipment, i.e CT SCAN SOMATOM DUO SOURCE, with a 128-slice detector (gantry rotation 0.33, slide thickness 0.5mm, gantry bore 7mm), manufactured in Germany by Siemens. A convenient sampling method, daily ongoing data collection was done on the respective days until the required sample size was achieved. Inclusion criteria were all CT scans ordered as head, head, and neck, and PNS, done at the Muhimbili national hospital and CT scan for patients aged 12years and above. We excluded CT scans with evidence of fracture of the ethmoid sinus, Pathologies with evidence of ethmoid bone erosion, post-PNS surgery and evidence of congenital anomalies of the craniofacial and sinuses. Ethical clearance was obtained from the Muhimbili university of health and allied sciences ethical committee.

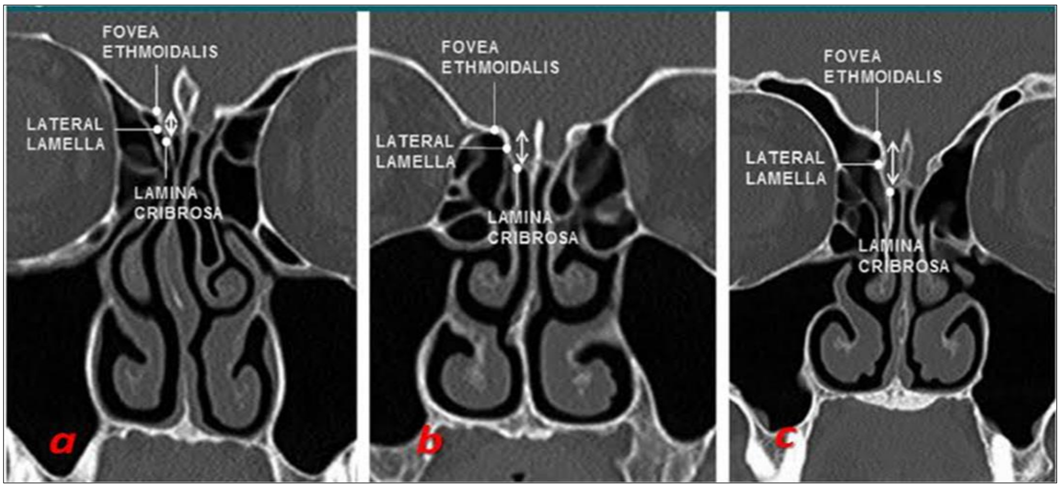

Figure A: a indicates Keros type I, b: Keros classification type II, and C: Keros type III

The data were collected and handled according to Helsinki declaration 1964. The sample size, n, of CT scans was calculated by using the formula, n= $Z^2p(1-p)/\epsilon^2$, where Z= Level of confidence interval which of 95% (1.96), P=prevalence of Keros type II in Kenya (67%), ϵ= margin of error of 5% (0.05). A sample size of 351 CT scans (702 sides) was recruited. The patients' CT scans that met the inclusion criteria were enrolled in the study, and every CT scan had its data checklist with a unique serial number. Data were collected by a principal researcher and assistant investigators. The information such as age, sex, and sides of the CT scan were gathered by using an information collection checklist. The height of the LLCB (olfactory fossa depth), the Keros classification and sides were all taken into account.

The data were obtained by using a digital computer screen by considering the standard anatomical points of reference. These anatomical points were the medial ethmoid roof (The point where lateral lamella of the ethmoid roof meets the medial end of the fovea ethmoidalis) and the cribriform plate (The point where the LLCP joins the cribriform plate). A horizontal line along each point was drawn, and then a vertical (perpendicular) distance between these points was measured, and this was the height of LLCP (Depth of the olfactory fossa). Measurements were taken on both left and right sides of each coronal view and then classified according to Keros Classification (Figure B).

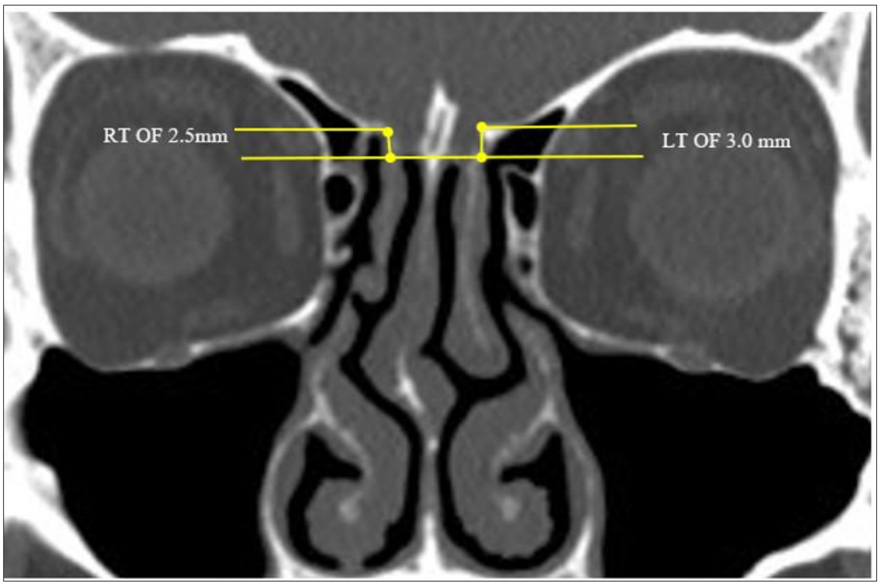

Figure B: Height of LLCP/Olfactory fossa depth measurements

Measuring of the ethmoid roof was done on both the right and left sides for assessment of asymmetry. CT scans with different Keros classifications between the right and left sides were considered asymmetrical, and those with the same Keros classification were considered symmetrical.

Data Management and Analysis

Data collected were entered into the SPSS software version 23 after being checked for completeness, accuracy, and internal constancy before analysis. The categorical data were summarized as proportions and analyzed using a Pearson Chi-square lest, while quantitative variables were summarized as the median. A confidence of 95% was used, and a p-value of ≤0.05% was considered Significant.

The distractive statistics provided a summary of the sample and all variables that were measured and presented in figures and tables. The categorical variables were analyzed using frequencies while quantitative variables, mean and standard deviation were calculated. The difference between proportions was assessed using the Chi-square test, and a p-value of ≤0.05% was considered significant.

RESULTS

A total of 702 sides were analyzed from 351 CT images. The study duration was 4months, from February 2022 to June 2022. Male patients accounted for 62.7%(n=220) of the 351 CT scans, whereas female patients accounted for 37.3% (n=131), with a female: male ratio of 1:1.7. Studied CT scans were obtained from patients ranged from 12 to 91 years, with a median age of 45. The age group 25-44 years accounted for 31.6% (n=111) of all cases, followed by the age group >60 years accounting for 26.8% (n=94), and the least common being <24 years,17.9% (n=63), (table 1).

Table 1: Demographic characteristics of the study sample(N=351)

Variable	Frequency (n)	Percent (%)
Age group (years)		
< 24	63	17.9
25 - 44	111	31.6
45 - 60	83	23.6
>60	94	26.8
Total	**351**	**100.0**
The median age in years (IQR)	45 (28, 61)	
Sex		
Male	220	62.7
Female	131	37.3
Total	**351**	**100.0**

Table 1 shows the social-demographic characteristics related to patients from whom their CT scans were recruited in our study where median age (IQR) was 45(28.61). About 62.7% and 37.3% of the CT scans were obtained from male and female patients respectively

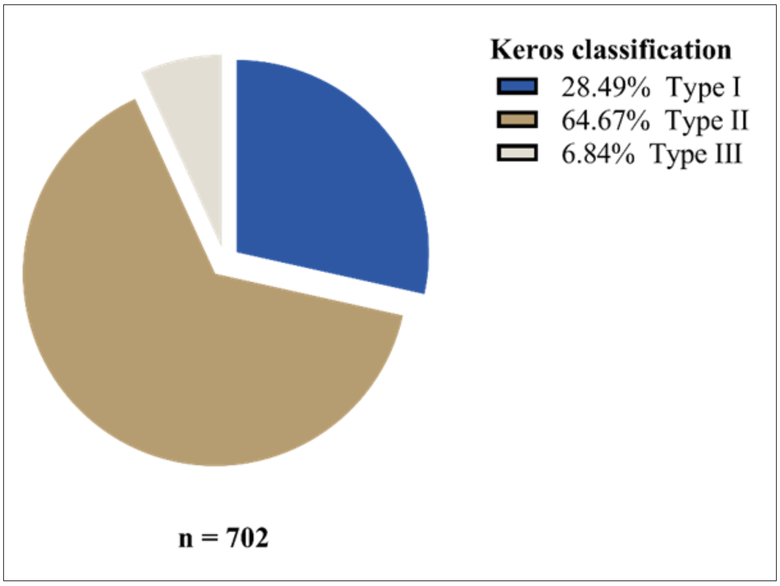

Figure1: Proportion of variations of olfactory fossae in 702 ethmoid roofs

Figure 1 shows the proportional distribution of the types of the ethmoid roofs in which Keros type II accounted for 64.67%, followed by type I, 28.49%, and the least common was type III, 6.84%.

Table 2: Distribution of olfactory fossae according to Keros classification by sex

		Sex			
Side of Keros	**Keros classification**	**Male n (%)**	**Female n (%)**	**Total N (%)**	**P-value**
Right					
	Type I	72 (32.7)	35 (26.7)	107(30.5)	0.126
	Type II	133 (60.5)	87 (66.4)	220(62.7)	
	Type III	15 (6.8)	9 (6.9)	24(6.8)	
	Total	**220(62.7)**	**131(37.3)**	**351(100.0)**	
Left	Type I	60 (27.3)	33 (25.2)	93(26.5)	0.547
	Type II	144 (65.5)	90 (68.7)	234(66.7)	
	Type III	16 (7.3)	8 (6.1)	24(6.8)	
	Total	**220(62.7)**	**131(37.3)**	**351(100.0)**	

Table 2 shows the distribution of olfactory fossae according to Keros classification by sex, where Keros type II was the most common in both males and females and the least common being type III. Despite being common in both males and females, the proportion of Keros type 2 was slightly higher in females than males, while Keros type 1 and type III were slightly higher in males than females.

Table 3: Distribution of olfactory fossae according to Keros classification by age

Keros classification		**Patients' age in years**					
		24 and less	**25-44**	**45-60**	**>60**		
		n (%)	**n (%)**	**n (%)**	**N (%)**	**Total (%)**	**P-value**
Right side	Type I	21(33.3)	29(26.1)	24(28.9)	33(35.1)	107(30.5)	0.668
	Type II	38(60.3)	74(66.7)	51(61.4)	57(60.9)	220(62.7)	
	Type III	4(6.3)	8(7.2)	8(9.6)	4(4.3)	24(6.8)	
	Total(N)	**63(17.9)**	**111(31.6)**	**83(23.6)**	**94(26.8)**	**351(100.0)**	
Left side	Type I	19(30.2)	27(24.3)	18(21.7)	29(30.9)	93(26.5)	0.716
	Type II	40(63.5)	75(67.9)	58(69.9)	61(64.9)	234(66.7)	
	Type III	4(6.3)	9(8.1)	7(8.4)	4(4.3)	24(6.8)	
	Total(N)	**63(17.7)**	**111(31.6)**	**83(23.6)**	**94(26.8)**	**351(100.0)**	

Table 3 shows the distribution of olfactory fossae according to Keros classification by age grou whereby Keros type II was the most common in all age groups, followed by type I, while type III was the least common.

Table 4: Distribution of olfactory fossae according to Keros classification by their sides

	Side of Keros			
Keros classification	**Right n (%)**	**Left n (%)**	**Total, N (%)**	**P-value**
Type I	107 (30.5)	93 (26.5)	200(28.5)	0.229
Type II	220 (62.7)	234 (66.7)	454(64.7)	
Type III	24 (6.8)	24 (6.8)	48(6.8)	
Total	**351(50.0)**	**351(50.0)**	**702(100.0)**	

Table 4 shows comparison of the distribution of the olfactory fossae by their sides whereby the most common type on both right and left sides was Keros type II, which accounted for 62.7% and 66.7%, respectively. Keros type II was lateralized to the left, while Keros type I was lateralized to the right side. On the other hand, type III was equally distributed between the right and left sides.

Among the 351 CT scans that were studied, 21.7% had asymmetrical Keros types (23.2% in males versus 19.1% in females). This means that in some individual CT scans, the two sides had different Keros types).

Table 5: Appearance of the ethmoid roofs between two individual CT scan sides

The appearance between right and left Keros types				
		Symmetrical n (%)	**Asymmetrical n (%)**	**Total N (%)**
Sex	**Male**	169(76.8)	51(23.2)	220(62.7)
	Female	106(80.9)	25(19.1)	131(37.3)
Total		**275(78.3)**	**76(21.7)**	**351(100.0)**

Table 5 shows the symmetry of distribution of the ethmoid roof types in male and female between the two sides of an individual CT scan whereby, asymmetry observed was 21.7% and 19.1% in males and females respectively. This means that two side of an individual CT scan may have a different Keros types.

DISCUSSION

Computed tomographic assessment of the ethmoid roof, particularly the olfactory fossae and position of the anterior ethmoid artery, is fundamental in a patient planned for functional endoscopic sinus surgeries (FESS). Evaluation aids in determining variations and identifying the potential for complications before surgery so that they can be minimized or avoided. Surgical injuries of the vital structures have been linked to these variations. Despite the importance of being aware of these differences, limited studies have been carried out in some countries, and no WHO data has been found in the literature. Only a few studies have been conducted in Africa, No data in Tanzania.

The CT scans included in this study were from the youngest patients, aged 12 years, to the oldest, aged 91 years, with a median age of 45 years. The female to male ratio was 1:1.7. The minimum age included in the study was similar to that of Souza *et al*., in Brazil [45], and that was done in India by Ashok *et al*., [14]. The reason could be that, the ethmoid sinus achieves adult size when a person attains age of 12 years.

According to this study, Keros type II ethmoid roof was the most common, accounting for 64.67% of the 702 ethmoid roofs/olfactory fossae (351 CT scans), followed by Keros type 1 (28.49 %) and type III (6.24%). Similar findings were observed in Brazil, India, Malaysia, Turkey, Iran, and Saudi Arabia [12-49], where Keros type II was most common, followed by type I. In east Africa, similar findings were observed in Kenya in 2014 [31]. Contrary to these findings, studies that were done in Oman, Iraq, the Philippines, and Egypt [9-51], observed that Keros type I was the most common, followed by type II, while the least common was type III. Furthermore, in Nigeria, contrasting results were reported, with Keros type III being the most common, followed by type II and I [30]. As a result, there was noticeable variation in Keros types, which could be explained by the inclusion of different ethnic populations, sample sizes, methodology, and race differences.

In this study, Keros type II was the most common across all age groups on both right and left ethmoid roofs, and the least common Keros type across all age groups was type III. Similar findings were observed in India by I. Salroo *et al*., [52], and in Kenya by F.Farah *et al*., [31]. Contrary to these findings, the study done in France by Ozlem *et al*., [53], observed that Keros type I was the commonest between the age of 1year to 9years, while type II was the commonest in the age above 9years. Differences in age inclusion criteria could account for the disparity as it is known that ethmoid sinuses reach adult size at the age of 12 years; hence they are considered underdeveloped before then.

Regarding distribution by sex, this study observed that Keros type II was the most common in both males and females (60.5% versus 66.4% respectively), followed by type I (33.7% versus 26.7%), and type III was the least common (6.8% versus 6.9%). The observed differences in proportions were statistically insignificant; therefore, they occurred only by chance($P>0.050$). These findings were comparable to those observed by D. Teja *et al*., in India [54], and Turkey by S. Erdogan *et al*., [55]. A similar distribution of Keros types between males and females was observed in the Philippines by J. Elfred *et al*., [28], and Turkey by H. Kaplanoglul *et al*., [49], though Keros type I was the most prevalent in both males and females.

Also, contrary to what was observed in this study, D. Ozrem *et al*., in France(53) found a significant variation in the distribution of Keros types between males and females, with type II being the most prevalent in males while type I being the most common in females. In Egypt, Shama *et al*., [9], found that there was a significant difference in the distribution of Keros classification between males and females, whereby the Keros type II was commonest in females while in males, Keros type I was the commonest. Variable ratios of males and females in the study samples, the inclusion of different populations, and race could all explain the observed disparities.

Regarding Keros classification of olfactory fossae by side, Keros type II was found to be the most common on both the right and left sides (62.7% versus 66.7%, respectively), followed by type 1 (30.5% versus 26.5%, respectively), and type III being the least common (6.8% versus 6.8%). As a result, both the right and left sides had the same distribution. Even though differences in proportions were observed, they occurred only by chance. Similar findings were observed in

Pakistan by Adeel *et al*., [36], Brazil by S.Souza *et al*., [45], Iraq by B. Natheer *et al*., [50], and India by Akshita *et al*., [54], and Egypt by Gisma *et al*., [56]. Different findings were observed in Italy by Fadda *et al*., [57], and in Saudi Arabia by Zyad *et al*., [48], where they observed a statistically significant difference in the Keros types distribution between the right and left sides. Keros type II was the commonest on the left, while type I was the commonest on the right. The disparity could be explained by the inclusion of people of various races and populations.

Furthermore, in this study, different Keros types were seen on the right and left sides of the same CT scan. The olfactory fossae in these images were regarded to be asymmetric. Asymmetrical Keros types between the right and left sides were found in 21.7% among 351 CT scans (23.1% in males versus 19.1% in females). Similar results were observed in India(23%) by Ashok et [14], and Egypt by Madani *et al*., [13], where asymmetry was observed in 22.5% of the CT scans (23.3% in males versus 19.9% in females). According to Kashibai *et al*., asymmetry was found in 11.5% of CT scans in India. The disparity in asymmetry prevalence could be attributed to differences in sample size and ethnicity. These findings necessitate a bilateral evaluation of the olfactory fossae before endoscopic sinus surgery because one side may have a higher risk of complications than the other.

CONCLUSION

Keros type II was the most commonly encountered ethmoid roof in this study. Keros type III, which is linked to the highest risk of iatrogenic complications during FESS was observed though was the least common.

However, age and gender did not affect the distribution of olfactory fossae. Also, the prevalence of asymmetry of Keros type between the right and left and right ethmoid roof in a single CT scan was found to be 21.7%.

Recommendations

Both olfactory fossae on the same CT scan should be assessed separately.

In patients scheduled for functional endoscopic sinus surgery, ENT and skull base surgeons should evaluation of the ethmoid roof for early identification of the higher risk ethmoid roofs and asymmetry prior surgery to minimize/avoid complications and included in the pre-operation checklist.

Due to scarcity of data, further studies are recommended at other medical institutions in Tanzania, East Africa, Africa and worldwide.

Abbreviation

AEA: Anterior ethmoid artery, CSF Cerebrospinal fluid, CT: Computed tomography, ESS: Endoscopic sinus surgery, FESS: Functional endoscopic sinus surgery, FE: Fovea ethmoidalis, LLCP: The lateral lamella of the cribriform plate, MNH: Muhimbili national hospital, MUHAS: Muhimbili University of Health and Allied Sciences OF: Olfactory fossa, PNS: Paranasal sinuses.

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Ethical Considerations

Ethical clearance was requested and provided from the Muhimbili university of health and allied sciences ethical committee. The data collection Checklists identified patients' CT scans by using serial numbers instead of using names. Confidentiality was paramount regarding data that were collected to ensure no information was traced back by the patients in the report or other forms of publication.

Conflict of Interest: We declare that there was no conflict of interest in this study

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