Med. J. Cairo Univ., Vol. 90, No. 5, September: 1499-1504, 2022
www.medicaljournalofcairouniversity.net

Radiographic Analysis of Ethmoid Roof Based on KEROS Classification among Egyptian People Using Multidector CT: A Cross-Sectional Study

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Abstract

Background: Endoscopic sinus surgery (ESS) is a commonly prescribed intervention not only indicated for chronic rhinosinusitis, but also applies to many disorders, such as mucocele, optic nerve decompression, sellar and parasellar tumors, and nasal polyposis.

Aim of Study: Evaluation of the height of ethmoid roof among the egyptian people using MDCT, classify the measurements according to Keros classification and determination of the incidence and degree of asymmetry in the height.

Material and Method: This study enrolled 1200 patients who were referred to from the ENT department to the radiology department over a period of 10 months from August 2020 to September 2021 at Al-Zahraa Hospital. We excluded non-adult (<18 years old), non-Egyptian patients to overcome racial variations and ethnic problems. The results were classified according to their Keros classification. Any asymmetries in the ethmoid roof depth and fovea ethmoidalis configuration were examined.

Results: The study enrolled 1200 patients, 542 males with a mean age of 34.81±9.35 years, and 658 females with a mean age of 33.35±8.42 years. The average height of the ethmoid roof was 4.85±0.70mm for males and 4.70±0.62mm for females with a statistically significant difference (p<0.001). The number of patients with Class I was 68 (5.7%), and the Class II was 1132 (94.3%). The frequency of Class I in males was 21 (3.87%), and Class II was 521 (96.13%). While, in females, the frequency of Class I was 47 (7.14%), and the Class II was 611 (92.85%). The average age of the Class I patients was 20.64±1.11 years and 34.81±8.49 years for Class II, with a significant difference between both classes (p<0.001). Cases were having asymmetric ethmoid roof with different classification type on either side of crista galli.

Conclusion: The majority of the studied population showed Keros Class II, followed by Class I. The frequency of Class II was higher in males and older population. Age and gender need to be assessed as predictors in future studies.

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Key Words: *CI: Confidence interval – CSF: Cerebrospinal fluid – CT: Computed tomography – ESS: Endoscopic sinus surgery – MDCT: Multi-detector computed tomography – SD: Standard deviation – PNS: Paranasal sinuses – ER: Ethmoid roof.*

Introduction

ENDOSCOPIC sinus surgery (ESS) is a commonly prescribed intervention not only indicated for chronic rhinosinusitis, but also applies to many disorders, such as mucocele, optic nerve decompression, sellar and parasellar tumors, and nasal polyposis **[1]**. However, this surgery associated with minor and major complications such as cerebrospinal fluid (CSF) leak, extra-ocularmuscle injury, bleeding, tooth or lip numbness, infection, ostial stenosis, and infections **[2]**. In the preoperative assessment of the paranasal sinuses (PNS), a radiographic examination by high resolution computed tomography (CT) has been considered the gold standard, which offers a "road map" of the ethmoid roof anatomy to the endoscopic sinus surgeon **[3]**. The ethmoid roof is created by the fovea ethmoidalis, which is an extension of the frontal bone, forms the ethmoidal roof of the bony labyrinth, and separates the anterior cranial fossa from the ethmoidal air cells **[4]**. Thus, the ethmoidal roof shares in the protection of olfactory nerve and bulb. The ethmoid roof is bounded medially bylateral lamella of the cribriform plate, which is a delicate bony structure with high liability for perforation during surgery **[5]**. The longitudinal limb is formed by the crista galli above the horizontal limb and the perpendicular plate below it (Fig. 1).

In some sources, the olfactory fossa (OF) and the area around the ethmoid cellular are called the 'danger zone' . Preoperative evaluation the olfactory fossa and its adjacent bone structures, ethmoid roof and anterior cranial fossa will lead to more safe surgical route that will decrease postoperative complications [6].

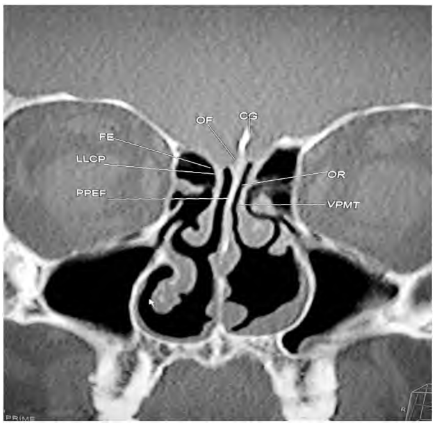

Fig. (1): The different anatomical structures of the ethmoid roof. CG: Crista galli, OF: Olfactoryfossa, FE: Fovea ethmoidalis, LLCP: Laterallamella of the cribriform plate, PPEB: Perpendicular plate of ethmoid bone, VPMT: Vertical plate of middle turbinate, OR: Olfactory recess.

According to the height of the lateral lamella of the cribriform plate, Keros has ivided the depth of the olfactory fossa into three classes (KEROS 1962).

Type I: Has depth of 1-3mm, type II: Has depth of 4-7mm, Type III: Has a depth of 8-16mm. In the first type, the ethmoid roof is very close to the cribriformplate; in contrast, in the third type, the ethmoid roof is lying on the cribriformplate (KEROS 1962). Keros'anatomical classification suggests that the risk of intracranial penetration during ESS procedure increased for longer lamellae. Therefore, the third classification is associated with the highest risk of intracranial penetration, which can result in CSF leakage and then meningitis during ESS [7].

Many studies showed that there is a difference between different populations in terms of ethmoidal roof-length based on Keros classification [8,9,10]. In Caucasians, the most frequent pattern is KerosII (50%) [11]. The same for Asians, 68.8% with Keros II, 19.3% with Keros III, and only 11.9% with Keros I [12]. There is a leak of information regarding the distribution of these classifications among Egyptians. Therefore, in this study, we aimed to investigate the distribution of ethmoidal roof based on Keros classifications among Egyptians.

Patients and Methods

Study design and setting:

This study enrolled 1200 patients who were referred to from the ENT Department to the Radiology Department in Al-Zahraa Hospital over a period of 12 months from August 2020 to September 2021. All procedures were done after informed consent from all patients. The ethical committee of participating hospital approved the study.

Exclusion criteria:

We excluded non-adult (<18 years old), non-Egyptian patients to overcome racial variations and ethnic problems. Moreover, any patient with facial anomalies or any type of ethmoid roof pathologies such as olfactory recess or olfactory fossa was excluded from the study.

Multi-detector CT (MDCT): The patient was informed of the investigation before being examined and told not to move during the scan. The patients were placed on their supine position. The head was attached to the headrest and symmetrically placed as possible. A scout lateral view was obtained and used for axial images preparation, which was taken without angulation (Tilt 0). The direct coronal scan was obtained, showing the full depth of olfactory fossa.For evaluation, we used 160-slices multi-detector CT (MDCT) machine (Toshiba Aquilionprime, Toshiba medical system corporation, Japan). We used high-resolution bone filter (70s sharp) and soft tissue to reconstruct the images. After that, we transferred the reconstructed axial images for manipulation of data. The multi-planar reformation was then developed at various planes. The height of the ethmoid roof was calculated, as reported in Shama and Montaser's study [13].

Coronal scan revealed the maximum depth of the olfactory fossa. Line A was a horizontal line passing through the most superior bony boundries of the inferior orbital foramina on both sides. Line B presenting the medial ethmoid roof, it was drawn perpendicular to line A extending from the site of connection of fovea ethmoidalis and lateral lamella of cribriform plate of ethmoid bone (LLCP)down to line A. Line C representing cribriform height, it was drawn perpendicular to line A extending from the most lateral bony boundry of cribriform plate of ethmoid at its communication with the lateral lamella to line A.

Keros's classification:

According to the height of the lateral lamella of the cribriform plate, Keros has divided the depth of the olfactory fossa into three classes (KEROS 1962). The olfactory fossa of type I is 1-3mm deep, 4-7mm deep for type II, and 8-16mm deep for type III. In the first type, the ethmoid roof is very close to the cribriformplate; in contrast, in the third type, the ethmoid roof is lying on the cribriformplate [13].

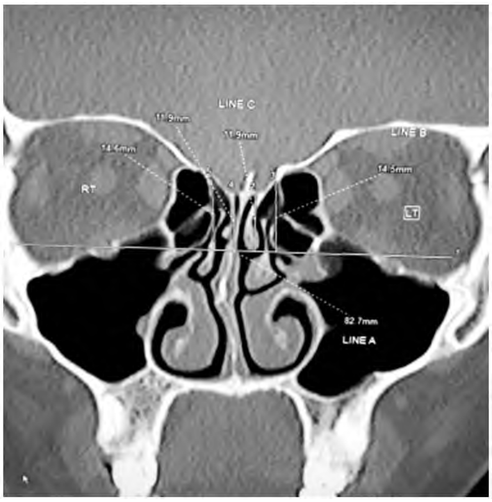

Fig. (2): Line A,B and Cused for measurement, The right h: 14.6-11.9=2.7mm, The left h: 14.5-11.9=2.6mm. Both are type I.

Fig. (3): The height of the ehmoid plate bilaterally Keris type II.

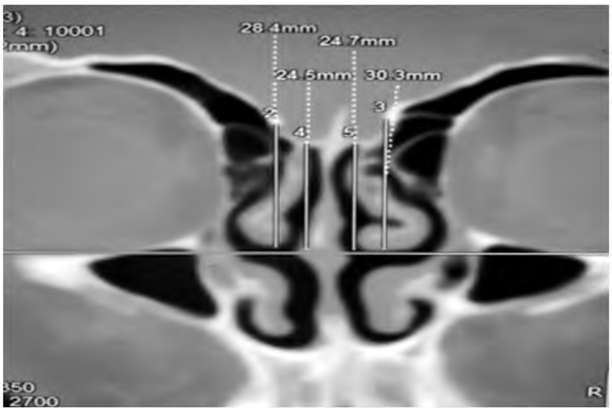

Fig. (4): Line A,B and C used for measurement, The right h: 28.4-24.3=4.1mm, The left h: 30.3-24.7=5.6mm. Both are type II.

Statistical analysis:

We performed a statistical analysis using the statistical package of social science (SPSS, windows version 22). All continuous quantitative data were presented in mean and standard deviation (SD). While categorical data were presented in frequencies and percentages. We used student *t*-test to compare means from both groups. The confidence interval (CI) used in this study was 95%. A *p*-value of less than 0.05 is considered significant.

Results

The study enrolled 1200 patients, 542 males with a mean age of 34.81±9.35 years, and 658 females with a mean age of 33.35±8.42 years. The average height of the ethmoid roof was 4.85± 0.70mm for males and 4.70±0.62mm for females with a statistically significant difference ($p<0.001$). The mean height of right side (Rt) and left side (Lt) in males was significantly ($p<0.001$) larger than females (Rt: 4.88±0.73mm vs. 4.72±0.65mm; Lt: 4.81±0.71mm vs. 4.69±0.64mm, respectively), Table (1).

Table (1): KEROS Classification Distribution.

Parameters	Male (n=540)	Female (n=658)	*p*-value
Class I	21	47	0.015
Class II	521	611	
Age	34.81±9.35	33.35±8.42	0.005
Right side	4.88±0.73	4.72±0.65	<0.001
Left side	4.81±0.71	4.69±0.64	0.001
Average	4.85±0.70	4.70±0.62	<0.001

In terms of Keros classification, the number of patients with Class I was 68 (5.7%), and the Class II was 1132 (94.3%). There was no Class III among our population. We found a significant difference between genders ($p=0.015$). The frequency of Class I in males was 21 (3.87%), and Class II was 521 (96.13%). While, in females, the frequency of Class I was 47 (7.14%), and the Class II was 611 (92.85%).

The average age of the Class I patients was 20.64±1.11 years and 34.81±8.49 years for Class II, with a significant difference between both classes ($p<0.001$). Regarding the average height, Class I patients was estimated to be 3.76±0.10mm, and Class II was 4.83±0.63mm ($p<0.001$). A significant difference ($p<0.001$) was observed between Class I and Class II in terms of Rt side height 3.68±0.21mm and 4.86±0.65mm, respectively. Similarly, the height of the Lt side was significantly ($p<0.001$) larger in Class II compared to Class I 4.80±0.66mm vs. 3.84±0.17mm, respectively, Table (2).

Table (2): Ethmoid roof according to KEROS classification.

Parameters	Class I	Class II	*p*-value
Age	20.64±1.11	34.81±8.49	<0.001
Right side	3.68±0.21	4.86±0.65	<0.001
Left side	3.84±0.17	4.80±0.66	<0.001
Average	3.76±0.10	4.83±0.63	<0.001

Discussion

The implementation and advancement of endoscopic sinus surgery required improved nose and sinus imaging. CT scan has become an important part of preoperative assessment because it is known as a guide for the surgeon **[15]**. Orbits, ethmoid air cells, and nasal cavities are found under the anterior cranial fossa, parallel to each other (from lateral to medial) **[16]**. Such anatomical regions are separated from the cranial cavity by the frontal and ethmoid bones **[17]**. The frontal bone's orbital plate makes the orbit roof, while the ethmoid bone's cribriform plate (lamina cribrosa) makes the nasal cavity roof **[18,19]**.

In this study, we highlighted the distribution of Keros classification of the ethmoid roof among the Egyptian population and its relation to the demographic data of the included population. Our findings showed that the majority ofthe Egyptian population (94.3%) were considered as Class II according to Keros Classification. Moreover, males and older ages are associated with longer ethmoid roof. As a reference point in the study, the anatomical location of the infraorbital nerves was taken, which is very important during ESS. Our study may help the surgeons know the location of the ethmoid roof. In the assessment of the anatomy that is highly variable, even between the two sides of a human, other studies have also used the same anatomical features of the coronal images **[20,21]**. These coronary sections are invaluable in the delivery of ESS in these dangerous areas. Another advantage for MDCT was reported by many studies, as the proper evolution of the ethmoid roof significantly helps in reducing the major complications of ESS **[22,23]**. Therefore, a deep understanding of the base of the skull is very critical in such procedures.

Unlike Keros classification, we considered that any measurement between 1-3.99mm as a Class I, 4-7.9mm as a Class II, and 8-12 as a Class III. Therefore, our findings are totally different from those of Keros, who found that about one-quarter of patients categorized under Class I and two-third of patients under Class II (KEROS 1962). This difference can be explained by the different ethnicity and the method of assessment. In different races and even among those carried out in the same race, there were significant differences in percentages. Such differences may be due to the broad range of participants, the measurement procedure, and even the standardization of classifications of Keros.

Similar to our findings, Elwany and his colleagues reported that Class II was more frequent in males, while Class I was more frequent in females. However, they reported a higher percentage of Class I (42.5%) compared to (5.7%) in this study. Moreover, they observed a high percentage of Class III in males (1.4%), but we could not find any case of Class III **[23]**. Another Egyptian study of Shama and Montaser demonstrated quite similar frequencies to Elwany et al., **[23,13]**. In the same direction, Indian, Chinese, and Malay populations showed that Class I was more distributed in females, and Class II was 3 more distributed in males **[24]**.

This study showed many limitations, as we did not comment on the symmetry or asymmetry between both sides of the ethmoid roof. Moreover, some important domains, such as the thickness of lateral lamella of the cribriform plate, the deepness, and the degree of angulation, were not assessed. In addition, we did not study the patients under 18 years.

Conclusion:

In conclusion, the majority ofthe studied population showed Keros Class II (94.3%), followed by Class I (5.7%). The frequency of Class II was higher in males and older population. Age and gender need to be assessed as predictors in future studies.

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التحليل الاشعاعى للسقف الغربالى بين المصريين بناءاً على تصنيف كيروس باستخدام الأشعة المقطعية متعددة المقاطع

الهدف : تقييم عمق الحفريات الشمية بين المصريين بناءً على تصنيف كيروس وتحديد مدى حدوث ودرجة عدم التناسق فى الارتفاع عن طريق التصوير بالأشعة المقطعية وتصنيف القياسات حسب تصنيف كيروس.

هدف العمل : تقييم ارتفاع السقف الغربالى بين المصريين باستخدام الأشعة المقطعية.

المواد والطريقة : ضمت هذه الدراسة ١٢٠٠ مريض تمت إحالتهم من قسم الأنف والأذن والحنجرة إلى قسم الأشعة على مدى ١٠ أشهر من أغسطس ٢٠٢٠ إلى سبتمبر ٢٠٢١ فى مستشفى الزهراء. استبعدنا المرضى غير البالغين (أقل من ١٨ عاماً) وغير المصريين للتغلب على الاختلافات العرقية والمشاكل العرقية. تم تصنيف النتائج حسب تصنيفها كيروس. تم فحص أى عدم تناسق فى عمق السقف الغربالى وتكوين النقرة الغربالى.

النتائج : ضمت الدراسة ١٢٠٠ مريض، ٥٤٢ ذكر بمتوسط عمر ٣٤.٨١±٩.٣٥ سنة، و ٦٥٨ إناث بمتوسط عمر ٣٣.٣٥±٨.٤٢ سنة. كان متوسط ارتفاع السقف الغربالى ٤.٨٥±٠.٧٠مم للذكور و ٤.٧٠±٠.٦٢مم للإناث مع وجود فرق معتد به إحصائياً (p<٠.٠٠١) بلغ عدد مرضى الصنف الأول ٦٨ (٥.٧٪)، والصنف الثانى ١١٣٢ (٩٤.٣٪). كان تواتر الصنف الأول عند الذكور ٢١ (٣.٨٧٪)، والصنف الثانى ٥٢١ (٩٦.١٣٪). بينما فى الإناث، كان نسبة الصنف الأول ٤٧ (٧.١٤٪)، والصنف الثانى ٦١١ (٩٢.٨٥٪). كان متوسط عمر مرضى الفئة الأولى ٢٠.٦٤±١.١١ و ٣٤.٨١±٨.٤٩ سنة سنة للفئة الثانية، مع وجود فرق كبير بين الفئتين (p<٠.٠٠١) كانت الحالات بها سقف غربالى غير متماثل بنوع تصنيف مختلف.

الخلاصة : غالبية السكان المدروسين أظهرو تصنيف كيروس من الدرجة الثانية، تليها الفئة الأولى. كان تكرار الدرجة الثانية أعلى عند الذكور وكبار السن. كما أنه يجب تقييم العمر والجنس كمتنبئين فى الدراسات المستقبلية.