The Egyptian Journal of Radiology and Nuclear Medicine (2015) 46, 929–936

Egyptian Society of Radiology and Nuclear Medicine

The Egyptian Journal of Radiology and Nuclear Medicine

www.elsevier.com/locate/ejrnm
www.sciencedirect.com

ORIGINAL ARTICLE

Variations of the height of the ethmoid roof among Egyptian adult population: MDCT study

Sherif A.M. Shama *, **Moataz Montaser**

Department of Radio-diagnosis, Faculty of Medicine, Alexandria University, Egypt

Received 14 June 2015; accepted 29 July 2015
Available online 19 August 2015

KEYWORDS

Ethmoid roof;
Olfactory fossa;
Lateral lamella;
Ethmoid bone;
Fovea ethmoidalis

Abstract Fovea ethmoidalis and lateral lamella of the cribriform plate of ethmoid bone (LLCP) are the most vulnerable parts of the skull base for iatrogenic complication during functional endoscopic sinus surgery. Keros classified the depth of the olfactory fossa into 3 types. According to Keros, the greater the height of LLCP, the higher the risk of its iatrogenic injury. The aim of this study was to evaluate variations of the height of ethmoid roof among Egyptian adults using MDCT. *Patients and methods:* This study was conducted on 100 Egyptian adult patients referred for MDCT evaluation of PNS. Patients with any pathology involving the ethmoid roof were excluded from the study. MDCT machines were used for evaluation of all patients. *Results:* The mean age of our patients was 38.34 ± 12.79 years. The right lateral lamella height ranges from 0.50 to 10.0 mm, while the left lateral lamella height ranges from 0.80 to 9.40 mm. Keros type I was seen in 56.5%, type II in 40.5% and type III in 3%. *Conclusion:* The majority of studied Egyptian adult population showed Keros type I (56.5%) followed by type II (40.5%). Keros type III is seen in only 3% of studied adult Egyptian population.

1. Background

The ethmoid cross is a key bony structure incorporated within the anterior skull base. It is formed by horizontal limb represented by the cribriform plate that forms the ethmoid roof separating the nasal recess of the nasal cavity below from the olfactory fossa above. The olfactory fossa is the most infro-medial portion of the anterior cranial fossa harboring the precious olfactory nerve and bulb. The longitudinal limb is formed by the crista galli above the horizontal limb and the perpendicular plate below it.

The fovea ethmoidalis (FE) is a part of the frontal bone that shares in the formation of the roof of the ethmoid bony labyrinth. It separates the ethmoidal air cells from the anterior cranial fossa. FE also medially articulates with the lateral lamella of the cribriform plate (LLCP). The shape of the contour of the fovea is determined by the angle at which the FE joins LLCP. FE may be straight or in the shape of a broken wing if the joint angle increases (1) (Fig. 1).

The LLCP is the thinnest bone of the entire skull base (2,3). FE and LLCP are the most vulnerable parts of the skull base

* Corresponding author at: Department of Radio-diagnosis, Faculty of Medicine, Alexandria University, Azarita, Alexandria, Egypt. Tel.: +20 1282012330, +20 34838483; fax: +20 34838480.
E-mail addresses: sh_shama@yahoo.com (S.A.M. Shama), moataz_m@hotmail.com (M. Montaser).

Peer review under responsibility of Egyptian Society of Radiology and Nuclear Medicine.

http://dx.doi.org/10.1016/j.ejrnm.2015.07.013
0378-603X

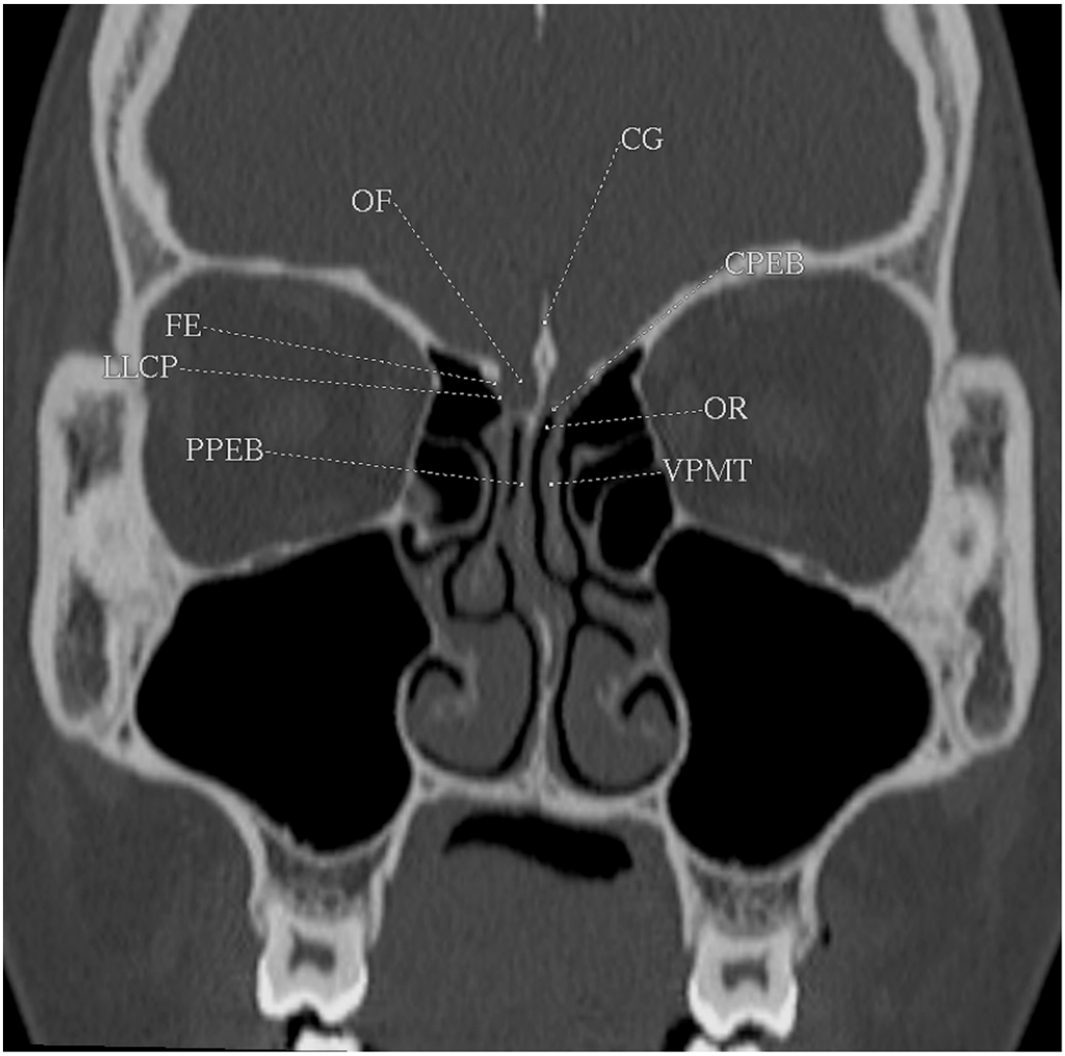

Fig. 1 The different anatomical structures of the ethmoid roof. CG crista galli, OF olfactory fossa, FE fovea ethmoidalis, LLCP lateral lamella of the cribriform plate, PPEB perpendicular plate of ethmoid bone, VPMT vertical plate of middle turbinate, OR olfactory recess.

for iatrogenic complication during functional endoscopic sinus surgery FESS (4,5).

In 1962, Keros (6) described differences in the horizontal level of the cribriform plate of the ethmoid bone. In his article written in German, he described three possible different levels and accordingly, he classified the depth of the olfactory fossa into 3 types. Since that time, this was known as Keros classification.

Keros classification depends on the length of the lateral lamella of the cribriform plate. This thin (mainly vertical) plate of bone is connecting the lateral boundary of the cribriform plate to the fovea ethmoidalis. The latter bony structure represents the bony roof of the ethmoid air cells (the ethmoid labyrinth) and actually is the most medial aspect of the orbital plate of the frontal bone forming the orbital roof.

In the original description by Keros (6): Keros I (26.3% of population), the olfactory fossa is 1–3 mm deep, the lateral lamella is short, and the ethmoid roof is almost in the same plane as the cribriform plate. In Keros II (73.3% of population), the olfactory fossa is from 4 to 7 mm deep, and the lateral lamella is longer. In Keros III (0.5% of population), the olfactory fossa is 8–16 mm deep, and the ethmoid roof lies significantly above the cribriform plate. Measurements between 3 and 4 mm as well as between 7 and 8 mm were not described.

According to Keros, the greater the height of LLCP, the higher the risk of its iatrogenic injury (7). Keros type III essentially exposes the thin LLCP to potential damage from trauma, surgery as well as tumor erosion, CSF erosion.

2. Aim of the work

The aim of this study was to evaluate variations of the height of ethmoid roof among Egyptian adults using MDCT. The study focused on the height of the lateral lamella of the cribriform plate (LLCP) and classified the measurements according to Keros classification.

3. Patients and methods

3.1. Inclusion criteria

This study was conducted on 100 Egyptian adult patients referred for MDCT evaluation of the para-nasal sinuses either for inflammatory or neoplastic process. Fifty patients (50%)

were males and 50 patients (50%) were females. All patients were adults exceeding 18 years old. The study was accepted from and performed in full accordance with regulations issued by the local ethics committee.

3.2. Exclusion criteria

Patients under 18 years old, those with facial anomalies and patients with any pathology involving the region of the ethmoid roof including both olfactory fossa and olfactory recess were excluded from the study.

To overcome the racial and ethnic problem and its effect on the skull configurations, we confined our work to the adult Egyptian population as the source of our patients in the everyday practice.

Eight slices multi-detector CT machine (Bright speed S, GE, USA) was used in assessment of all patients. Before imaging, the patient was informed about the investigation and instructed not to move during scanning. The patients were in supine position. The head was strapped to the head rest and positioned as symmetrically as possible. A lateral scout view was taken and used for planning the axial images. Axial images were taken without any angulations (Tilt 0). The protocol was 120 mA, 120 kV, 1.2 mm slice thickness, large field of view (FOV) and 1.35 pitch.

All images were prospectively reconstructed at 0.625 mm, using soft tissue and high-resolution bone filter (70s sharp). The reconstructed axial images were transferred to Advantage 4.4 GE, USA workstation for manipulation of data. Then multi-planar reformation (MPR) was generated in different planes.

Direct coronal scan showing the maximum depth of the olfactory fossa was obtained. Line A was drawn as direct horizontal line connecting the most superior bony boundaries of the inferior orbital foramina on both sides. Line B was drawn as a direct vertical line connecting line A and to the site of communication of fovea ethmoidalis (the most medial aspect of the orbital plate of the frontal bone forming the orbital roof) and the lateral lamella of the cribriform plate of the ethmoid bone (LLCP). Line C was drawn as a direct vertical line connecting line A to the most lateral bony boundary of the cribriform plate of the ethmoid bone at its communication with the lateral lamella. Line B was representing the medial ethmoid roof height while line C was representing cribriform plate height (Fig. 2).

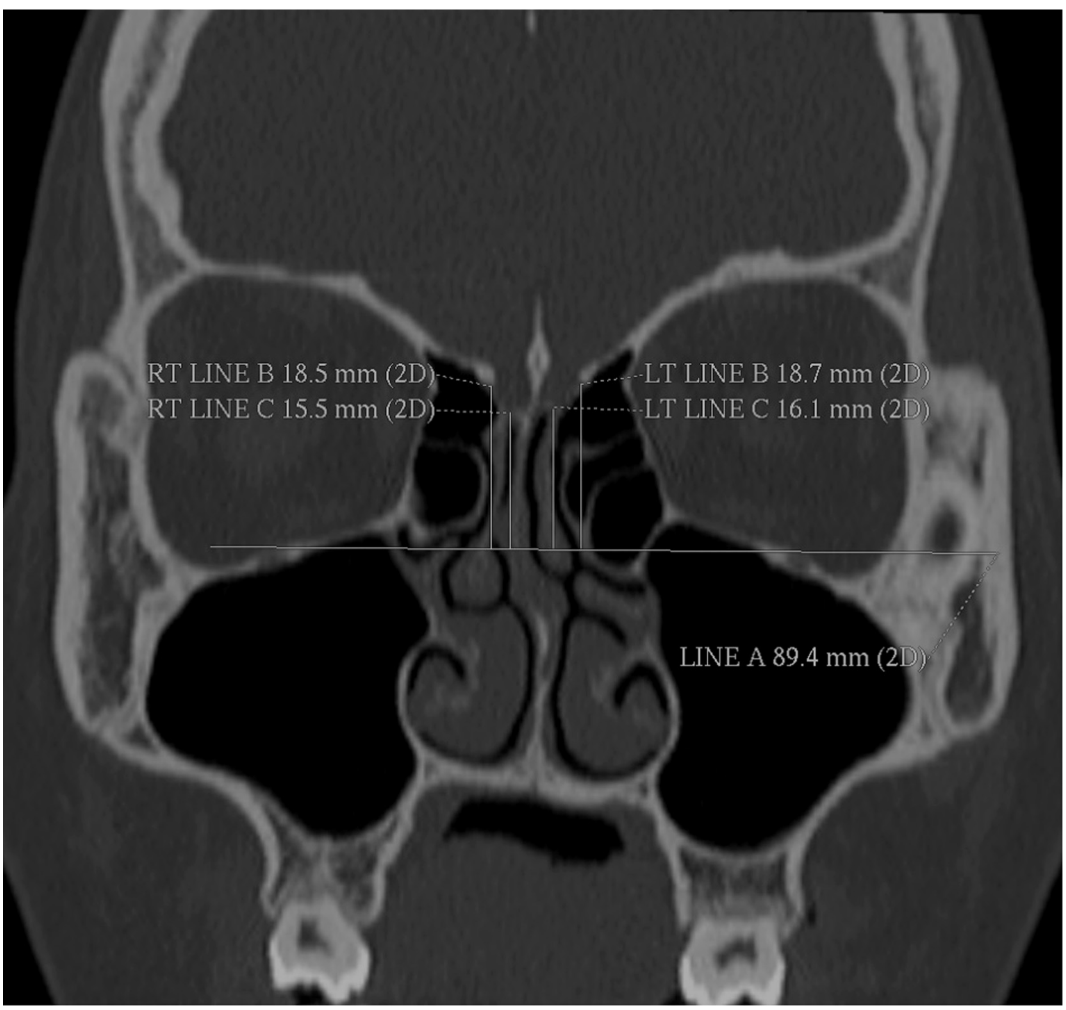

Fig. 2 Lines A, B and C used for measurements are demonstrated. The right $h = 18.5–15.5 = 3$ mm. The left $h = 18.7–16.1 = 2.6$ mm. Both are of type I. Both LLCP showed mild asymmetry with different degrees of vertical angulation. The left LLCP is less vertically oriented. The left side of the cribriform plate of ethmoid bone is relatively in a higher position compared to the right side.

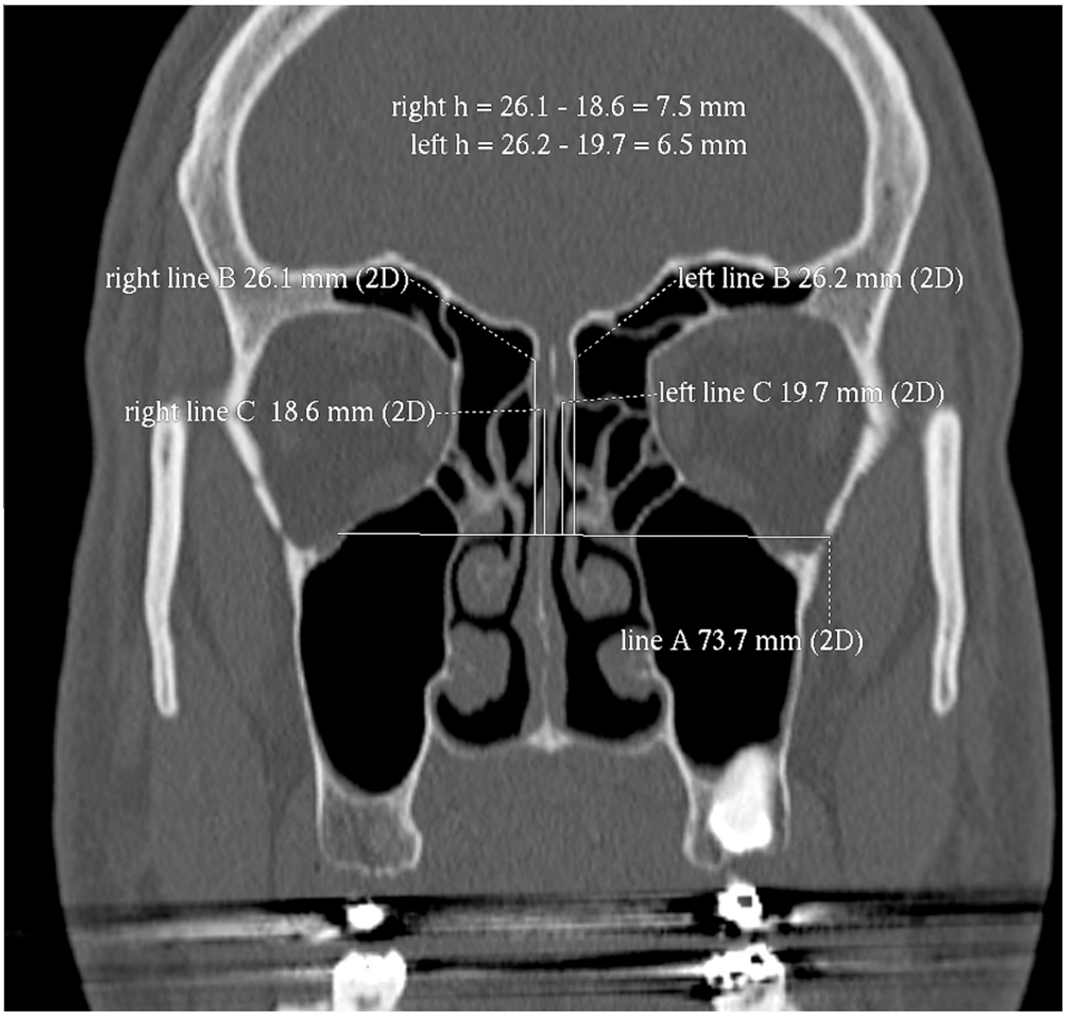

Fig. 3 Bilateral Keros Type II olfactory fossae. Note the slight asymmetrical height in depth as well as the slight asymmetrical height of the cribriform plate of ethmoid bone by comparing the lengths of line C on both sides. The left side is higher by 19.7–18.6 = 1.1 mm.

The height of the ethmoid roof (*h*) was considered as depth of the olfactory fossa. "*h*" was calculated as the result of subtraction of length of line C "*c*" from the length of line B "*b*" in millimeters ($h = b - c$). "*h*" was representing the direct vertical height of the lateral lamella of the cribriform plate of the ethmoid bone (LLCP) that showed different degrees of vertical angulation according to different modeling of the anterior skull base.

Measurements between 0 and less than 4 mm were considered as type I Keros. Measurements more than 4 mm and less than 8 mm were considered type II Keros. Type III Keros patients showed measurements of 8 mm and more. In original Keros classification measurements more than 3 and less than 4 as well as more than 7 and less than 8 mm are not described. Current available MDCT software is capable of sub-millimeter measuring (Figs. 2 and 3).

4. Statistical analysis

We used SPSS 17.0 for the statistical analysis. The collected data were evaluated using the descriptive statistical methods (the mean, standard deviation and median). Measurements between the right and left sides were compared. The results were categorized according to Keros classification, and their distributions were analyzed according to gender. We calculated p value for Student t-test for comparing between the means of right and left sides and p value for Paired t-test for comparing between the means of paired right and left sides as well as r: Pearson coefficient for correlation between right and left sides. We also calculated p value for Monte Carlo test for comparing between males and females regarding Keros type. Statistical significance was $p \leqslant 0.05$.

5. Results

MDCT scans of the 100 adult Egyptian patients were analyzed. Half of these cases (50 cases) were males and the other half were females. The ages of the patients ranged between 18 and 74 years with a mean of 38.34 ± 12.79 years. The mean age of males was 38.74 ± 11.60 years and the mean age of females was 37.94 ± 13.93 years. The average direct vertical height of LLCP (the average height of the ethmoid roof or "*h*") was 4.92 ± 1.70 mm, and the median was 4.90 mm (0.9–10.5). The average "*h*" was 4.87 ± 1.71 mm for the right side and 4.91 ± 1.66 mm for the left side. The average difference between the right and left sided "*h*" was not statistically significant ($p = 0.785$). The average "*h*" was found to be lower on the right side (Table 1).

When the right and left sided "*h*" were compared for each individual, asymmetry (a height difference between two sides of more than 1 mm) was found in 31 cases (31%). A lower left sided ethmoid roof (higher h value) was found in 18 cases (18%), and a lower right sided ethmoid roof (higher h value) was found in 13 cases (13%). The distribution of the differences between the right and left "*h*" according to gender is presented in Tables 2 and 3.

Table 4 shows the distributions of patients according to Keros classification, the lateral lamella of cribriform plate (LLCP) height complies with Keros Type I in 113 (56.5%) sides, Keros Type II in 81 (40.5%) sides, and Keros Type III in 6 (3%) sides.

About two thirds (66%) of the olfactory fossa in females were of Type I and nearly the other third (33%) were of type II. In female patients, only one olfactory fossa was of type III. On the other hands 5 olfactory fossae in males were of type III. Type I and Type II represent 47 and 48 fossae in males respectively. Type I was the commonest in females while type II was slightly common than type I in male patients. Type III was encountered more commonly in males.

The mean LLCP height was 2.70 ± 0.78 mm in Keros Type I cases, 5.21 ± 0.99 mm in Keros type II cases, and 8.77 ± 0.81 mm in Keros Type III cases. Table 5 shows the tabulated results for both sides.

Table 1 Relation between sex and age.

	Sex		Overall ($n = 100$)
	Male ($n = 50$)	Female ($n = 50$)	
Age			
Median	38.0	36.0	37.50
(Range)	(18.0–70.0)	(18.0–74.0)	(18.0–74.0)
Mean ± SD	38.74 ± 11.60	37.94 ± 13.93	38.34 ± 12.79

Table 3 Distribution and percentage values of the cribriform plate lateral lamella depth in symmetry–asymmetry (low ethmoid roof) groups.

	Sex		Total
	Male	Female	
Right > Left with > 1 m	6 (12.0)	7 (14.0)	13 (13.0)
Left > Right with > 1 m	10 (20.0)	8 (16.0)	18 (18.0)
Total asymmetry (right or left)	16 (32.0)	15 (30.0)	31 (31.0)
Symmetry	34 (68.0)	35 (70.0)	69 (69.0)
Overall (symmetry + asymmetry)	50 (100.0)	50 (100.0)	100 (100.0)

Table 4 Relation between Keros Type and sex.

	Sex		Overall
	Male	Female	
Keros Type			
Type I (1–3.9)	47 (47.0)	66 (66.0)	113 (56.5)
Type II (4–7.9)	48 (48.0)	33 (33.0)	81 (40.5)
Type III (8–12)	5 (5.0)	1 (1.0)	6 (3.0)
p	0.013*		

p: *p* value for Monte Carlo test for comparing between males and females regarding type.
* Statistically significant at $p \leqslant 0.05$.

Table 2 Relation between sex and height in right and left side.

	Height		Overall
	Right	Left	
Male	($n = 50$)	($n = 50$)	($n = 100$)
Median (Range)	3.95 (0.50–10.0)	4.10 (1.30–4.90)	4.0 (0.50–10.0)
Mean ± SD	4.12 ± 1.90	4.23 ± 1.83	38.74 ± 11.60
p	$p_1 = 0.777$, $p_2 = 0.423$		
r (*p*)	0.877* (<0.001)		
Female	($n = 50$)	($n = 50$)	($n = 100$)
Median (Range)	3.20 (1.40–8.0)	3.30 (0.80–7.0)	3.20 (0.80–8.0)
Mean ± SD	3.61 ± 1.69	3.64 ± 1.40	37.94 ± 13.93
p	$p_1 = 0.928$, $p_2 = 0.844$		
r (*p*)	0.807* (<0.001)		
Overall	($n = 100$)	($n = 100$)	($n = 200$)
Median (Range)	3.45 (0.50–10.0)	3.80 (0.80–9.40)	3.80 (0.50–10.0)
Mean ± SD	3.87 ± 1.81	3.93 ± 1.65	38.34 ± 12.79
p	$p_1 = 0.785$, $p_2 = 0.487$		
r (*p*)	0.849* (<0.001)		

p_1: *p* value for Student *t*-test for comparing between the means of right and left.
p_2: *p* value for Paired *t*-test for comparing between the means of paired right and left.
r: Pearson coefficient for correlation between right and left.
* Statistically significant at $p \leqslant 0.05$.

Table 5 Relation between Keros Type and height in right and left side.

	Keros Type		
	Type I	Type II	Type III
Right			
Median (Range)	2.80 (0.50–3.90)	5.15 (4.0–7.90)	8.10 (8.0–10.0)
Mean ± SD	2.66 ± 0.79	5.36 ± 1.08	8.70 ± 1.13
Left			
Median (Range)	2.75 (0.80–3.90)	4.90 (4.0–7.10)	8.90 (8.20–9.40)
Mean ± SD	2.75 ± 0.77	5.08 ± 0.88	8.83 ± 0.60
Overall			
Median (Range)	2.80 (0.50–3.90)	5.10 (4.0–7.90)	8.55 (8.0–10.0)
Mean ± SD	2.70 ± 0.78	5.21 ± 0.99	8.77 ± 0.81

6. Discussion

Both orbits, ethmoid air cells and nasal cavities are located adjacent to each other (from lateral to medial) below the anterior cranial fossa. The frontal and ethmoid bones are separating these anatomical regions from the cranial cavity. The orbital plate of the frontal bone makes the roof of the orbit, while the cribriform plate of ethmoid bone (lamina cribrosa) makes the roof of the nasal cavity.

Both ethmoid and frontal bones share in the formation of the roof of the ethmoid air cells. The lateral lamella of cribriform plate of the ethmoid bone (LLCP) or the lamina lateralis extends laterally showing different degrees of vertical angulations among different individuals and among both sides in the same individual. This will be determined by the shape and modeling of the anterior skull base and expected to have a high degree of variability among population.

LLCP articulates laterally with the most medial aspect of the orbital plate of the frontal bone that is called fovea

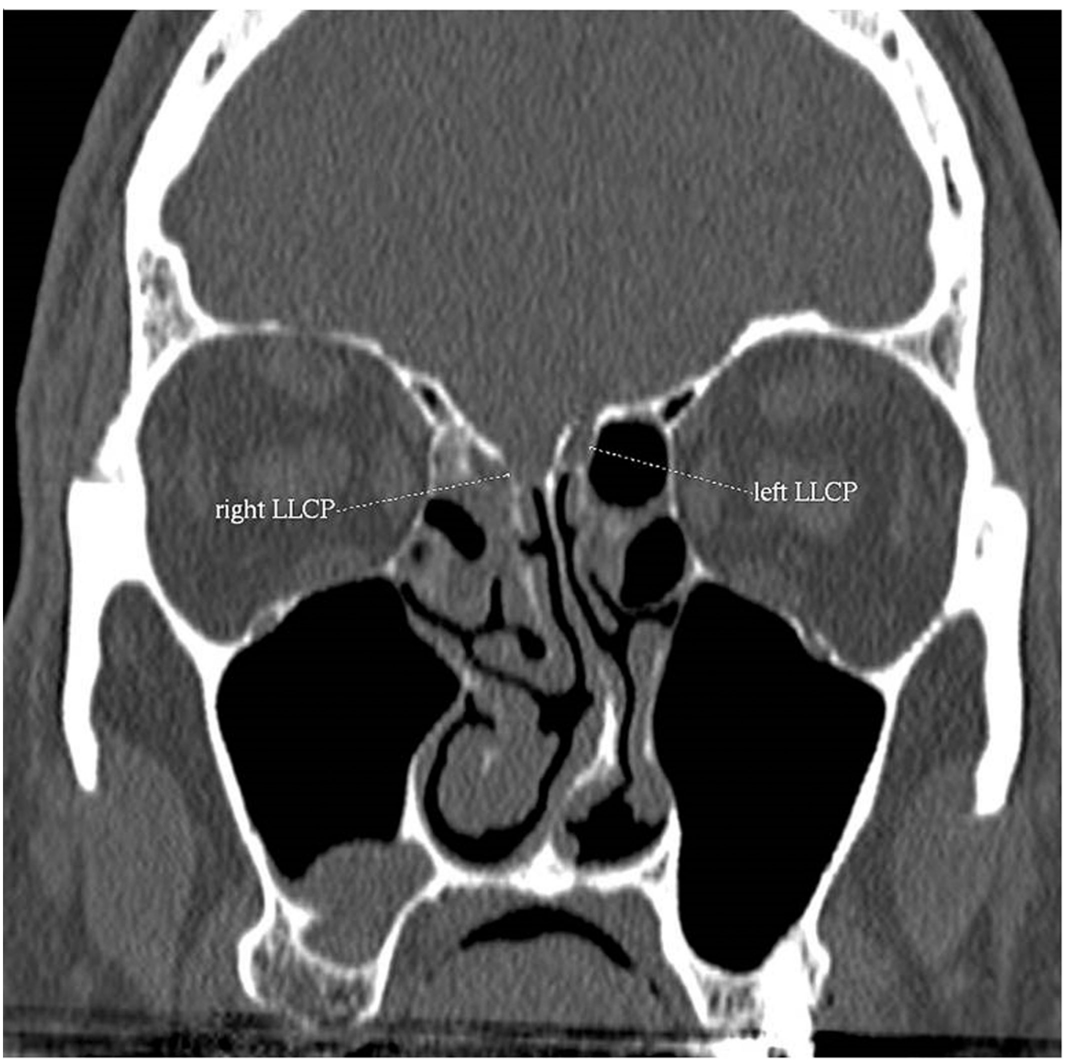

Fig. 4 Asymmetry in configuration of both olfactory fossa. On the ride, the fossa is broader and slightly deeper. The LLCP is less vertical than on the left side.

ethmoidalis (FE). Both LLCP and FE are forming the bony roof of the ethmoid air cells.

The FE as part of the frontal bone is dense and thick. It forms the strong lateral side of bony roof of the ethmoid air cells. The LLCP as part of ethmoid bone is thin. It is the thinnest bony plate of the entire skull base. Its thickness is between 0.05 and 0.2 mm. LLCP forms the weak medial side of bony roof of the ethmoid air cells and consequently the most vulnerable area for iatrogenic injury and intracranial perforation during FESS (8). We used the site of transition from thick to thin bone as a guide for accurate localization between the articulation between the FE and LLCP and used this point for measurement (line B).

As mentioned, the degree of vertical angulation of the LLCP varies (Fig. 4). The angle of articulation of LLCP and FE defines the shape of the olfactory fossa from the intracranial side as well as the height of the ethmoid roof and depth of the olfactory recess from the nasal side. Being sides of a right angle triangle, the depth of the olfactory fossa is directly related to both length and degree of vertical angulation of the LLCP. LLCP is representing the hypotenuse of this right angle triangle.

As the vertical depth of LLCP increases (the more vertical position of LLCP), the olfactory fossa tends to be narrower and deeper and the ethmoid roof will be more low and hanging. This will increase the risk of iatrogenic injury of the LLCP.

More than two thirds of our patients (69%) showed symmetrical height of ethmoid roof when the right and left sided "*h*" were compared for each individual. Asymmetry or height difference between two sides of more than 1 m was found in 31 cases (31%). The right ethmoid roof had more chance to be lower than the left ethmoid rood and therefore, theoretically it may be more susceptible for iatrogenic injury.

Some other studies have demonstrated that the lateral lamella of the cribriform plate is symmetrical in less than 50% of individuals, and that this asymmetry is related to flattening of the fovea ethmoidalis with angulation of the lateral lamella of the cribriform plate, which may result in surgical difficulties (1,8,9).

In original Keros classification (6), Type I was described in 26.3% of population, versus 56.5% in our study. Keros Type II olfactory fossa described in 73.3% of population, versus 40.5% in this study. The olfactory fossa of Keros III was described in 0.5% of population, versus 3% in our study. This study was done on Egyptian population and we used more accurate measurements based on MDCT. In original Keros classification measurements more than 3 and less than 4 as well as more than 7 and less than 8 mm are noted described. In our study we considered measurements more than 3 and less than 4 mm as type I Keros as well as measurements more than 7 and less than 8 mm as Keros III.

In Table 6 we compared incidence of different Keros types among different studies performed among different races. There were wide variations in the percentages among the studies performed in different races and even among those performed on the same race. These variations may be attributed to the wide range in number of studied patients, method of measurements and even the standardization of Keros classifications regarding the originally non described measurements (more than 3 and less than 4 as well as more than 7 and less than 8 mm).

Table 6 Keros classification among different studies.

Author	Country	Keros I (%)	Keros II (%)	Keros III (%)
Original Keros (6)	Germany	26.3	73.3	0.5
This study	Egypt	56.5	40.5	3.0
Elwany et al. (10)	Egypt	42.5	56.8	0.7
Kaplanoglu et al. (8)	Turkey	13.4	76.1	10.5
Şahin et al. (15)	Turkey	10.0	61.0	29.0
Erdem et al. (16)	Turkey	8.1	59.6	32.3
Solares et al. (5)	USA	83.0	15.0	2.0
Souza et al. (2)	Brazil	26.3	73.3	0.5
Paber et al. (4)	Philippine	81.8	17.7	0.5
Bista et al. (17)	Nepal	86.0	12.0	2.0

In another study among the Egyptian population, Elwany et al. (10) classified 42.5% of the cases as Keros Type I and 56.8% of the cases as Keros Type II. Keros Type III was found in 1.4% of the men and in none of the women. We agreed with Elwany et al. (10) that Keros Type II and III are more frequently in men, and Keros Type I is more frequently in women.

In this study we used cross sectional MDCT in our measurements. The anatomical site of the infra-orbital nerves was taken as the reference point for measurements in this study. This reference point is more relevant during surgery and endoscopic sinus surgery. We could assist in informing the surgeons about the position of the ethmoid roof. Other studies (4,8,11,12) also used the same anatomical landmarks in the coronal images that represent road maps in the evaluation of the anatomy which is highly variable even between the two sides of the same person. These coronal MDCT sections are invaluable in demonstrating areas at risk for complications in the planning of endoscopic sinus surgeries.

The majority of the major complications of functional endoscopic sinus surgery are related to the ethmoid bone (13). Several studies highlight the relevance of the evaluation of the ethmoid roof and its value in the prevention of FESS complications (13,14). To avoid major complications, anatomical variations, particularly in the base of the skull, should be properly understood and reported (2,3).

Limitations of this study included the limited number of patients, the choice of the patients randomly throughout the entire adulthood life and not, more specifically, within the different decades of life. Patients below 18 years were also not studied.

We concluded that the majority of studied Egyptian adult population showed Keros type I (56.5%) followed by type II (40.5%). Keros type III is seen in only 3% of studied adult Egyptian population.

Conflict of interest

The authors declare that there are no conflicts of interest.

References

(1) Terrier F, Weber W, Ruefenacht D, Porcellini B. Anatomy of the ethmoid: CT, endoscopic and macroscopic. AJR, Am J Roentgenol 1995;144:493–500.

(2) Souza SA, Souza MMA, Idagawa M, Wolosker AMB, Ajzen SA. Computed tomography assessment of the ethmoid roof: a

relevant region at risk in endoscopic sinus surgery. Radiol Bras 2008;41(3):143–7.

(3) Luong A, Marple BF. Sinus surgery: indications and techniques. Clin Rev Allergy Immunol 2006;30:217–22.

(4) Paber JAL, Cabato MSD, Villarta RL, Hernandez JG. Radiographic analysis of the ethmoid roof based on KEROS classification among filipinos. Philippine J Otolaryngol Head Neck Surg 2008;23(1):15–9.

(5) Solares CA, Lee WT, Batra PS, Citardi MJ. Lateral lamella of the cribriform plate. Software-enabled computed tomographic analysis and its clinical relevance in skull base surgery. Arch Otolaryngol Head Neck Surg 2008;134(3):285–9.

(6) Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. Z Laryngologie, Rhinologie, Otologie Ihre Grenzgeb 1962;41:808–13.

(7) Ulualp SO. Complications of endoscopic sinus surgery: appropriate management of complications. Curr Opin Otolaryngol Head Neck Surg 2008;16:252–9.

(8) Kaplanoglu H, Kaplanoglu V, Dilli A, Toprak U, Hekimoğlu B. An analysis of the anatomic variations of the paranasal sinuses and ethmoid roof using computed tomography. Eurasian J Med 2013;45:115–25.

(9) Keros P. On the practical importance of differences in the level of the cribriform plate of the ethmoid. Laryngol Otol (Stuttg) 1965;41:808–13.

(10) Elwany S, Medanni A, Eid M, Aly A, El-Daly A, Ammar SR. Radiological observations on the olfactory fossa and ethmoid roof. J Laryngol Otol 2010;124:1251–6.

(11) Stammberger H. Endoscopic anatomy of lateral wall and ethmoidal sinuses. In: Stammberger H, Hawke M, editors. Essentials of functional endoscopic sinus surgery. St. Louis: Mosby-Year Book; 1993. p. 13–42.

(12) Kainz J, Stammberger H. The roof of the anterior ethmoid: a locus minoris resistentiae in the skull base. Laryngol Rhinol Otol (Stuttg) 1988;67:142–9.

(13) Dessi P, Castro F, Triglia JM, Zanaret M, Cannoni M. Major complications of sinus surgery: a review of 1192 procedures. J Laryngol Otol 1994;108:212–5.

(14) McMains KC. Safety in endoscopic sinus surgery. Curr Opin Otolaryngol Head Neck Surg 2008;16:247–51.

(15) Şahin C, Yılmaz YF, Titiz A, Özcan M, Özlügedik S, Ünal A. Analysis of ethmoid roof and cranial base in Turkish population. KBB ve BBC Dergisi 2007;15:1–6.

(16) Erdem G, Erdem T, Miman MC, Ozturan O. A radiological anatomic study of the cribriform plate compared with constant structures. Rhinology 2004;42:225–9.

(17) Bista M, Maharjan M, Kafle P, Shrestha S, KC T. Computed tomographic assessment of lateral lamella of cribriform plate and comparison of depth of olfactory fossa. J Nepal Med Assoc 2010;49(178):92–5.