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Original Article

Computed Tomography Analysis of the Ethmoid Roof: A Region at Risk in Endoscopic Sinus Injury

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Abstract

Objective: To determine the olfactory fossa depth according to the Keros classification and determine the incidence of asymmetry in height and configuration of the ethmoid roof.

Materials and Methods: Retrospective analysis of 75 coronal computed tomography studies of paranasal sinuses and facial bones were performed. Measurement of the depth of the lateral lamella, classification of the depth according to Keros type and determination of the asymmetries in the ethmoid roof depth and configuration were done.

Results: The mean height of the lateral lamella cribiform plate (LLCP) was 2.15±1.29 mm. The cases were classified as 87.33% Keros type1 and 12.67 % as Keros type 2. No Keros type 3 was found .There was asymmetry in the LLCP height of 33.33% of cases and a configuration asymmetry in 8% of the cases.

No significant difference between the mean height and distribution of Keros type between gender and laterality were also found.

Conclusion: As regards the olfactory fossa depth, the Keros type 1 was most frequently found. Asymmetry in the depth and configuration were detected in 33.33 and 8% respectively. Risk of inadvertent intracranial entry through the lateral lamella among Thai may be lower than other studies with majority of cases classified as Keros type 2 or 3.

Keyword: Ethmoid roof, Keros type

Introduction

Endoscopic sinus surgery (ESS) is now considered as the treatment of choice for chronic rhinosinusitis which is resistant to medical treatment as well as for other diseases such as mucocele, nasal polyposis, sellar and parasellar tumors, choanal atresia, and optic nerve decompression.[1] There may be intraoperative complications because this surgery is performed in a complex anatomy. The complications are categorized into minor and major types. Minor complications occur in 1.1-20.8% of the cases which are hemorrhage, infection, cohesion, narrowing in the ostium, insensitivity the teeth or lips and the relapse of the disease. The major complications are cerebrospinal fluid leakage, ocular trauma, meningitis or intracranial penetration which occur in 0-1.5% of cases.[2-4]

Most of major complications are related to surgical manipulation of the ethmoid and frontal sinuses. The roof of the ethmoidal labyrinth is formed by the fovea ethmoidalis; an extension of the frontal bone orbital plate separating the ethmoidal cells from the anterior cranial fossa. It connects with the lateral lamella of the cribiform plate (LLCP), the thinnest bone of the skull base.[5,6] The fovea ethmoidalis and the lateral lamella both are the most vulnerable skull base to be injured during ESS.[6,7] In 1962, Keros determined the depth of the olfactory fossa into 3 types according to the height of the lateral lamella as Table 1.

Depending on the Keros type,the greater the depth of olfactory fossa, the higher the risk of its penetration into the anterior cranial fossa is.[8] Besides the depth of olfactory fossa, one factor which may cause surgical difficulties is the configuration of the ethmoid roof. Asymmetry of the height of the ethmoid roof between two sides must be determined as well as the variation in their contour. The shape of the contour is identified by the angle at which the fovea ethmoidalis joins with the cribiform plate. It may be straight or in the shape of a broken wing if the angle increase.[9] This angulation may result in surgical difficulties. That is why the knowledge about the complex skull base anatomy and variation is essential for pre-operative evaluation in endoscopic nasal surgeries.

Computed tomography (CT) has become the potential investigation not only to evaluate of sinonasal disease, but also to be a road map in characterization of the paranasal sinus anatomy in the planning of ESS.[8]

The reasoning of this study are evaluation the depth of the olfactory fossa, characterization them according to Keros classification, and determination the asymmetry of the ethmoid roof. The end goal is to gather this knowledge for the surgeons in an effect to reduce the surgical complications.

Table 1 Three types of Keros classification according to the height of lateral lamella

Height of lateral lamella : Depth of olfactory fossa (mm)	Keros type
0-3	1
4-7	2
8-16	3

Materials and Methods

Retrospective analysis of all paranasal sinus an facial bone CT acquired in the period between June 2013-May 2014 in Lerdsin General hospital were done. The exclusion criteria were patients under the age of 16, previous history of trauma or surgery in the paranasal sinuses or skull base, sinonasal tumor and serious rhinosinusitis. Seventy five CT studies were included in this study. This study was approved by the Human Ethics Committee of Lerdsin General hospital.

All CT studies were performed using a 64 multi-slice CT equipment. (Somatom Definition AS Siemen) The technical parameter are shown in Chart 1.

Only coronal images were utilized in this study. The images were acquired perpendicular to the hard palate from the anterior margin of the frontal sinus to the anterior margin of the clivus. All images were evaluated by the same radiologist. The ethmoid roof measurement was performed manually using a digital screen. The standard anatomic points were determined such as the medial ethmoid roof point, the cribiform plate point and the infraorbital nerve point.

Measurements were performed using the distance measurement technique in the coronal plane. The horizontal line crossing between both infraorbital neural foramen were performed. The vertical line drawn from the medial ethmoid roof to the horizontal plane was measured and defined as the medial ethmoid roof height (MEH). The length of a vertical line from the cribiform plate to the horizontal line was defined as the cribiform plate height (CPH). The height of the lateral lamellar (LLH) was the result of subtracting the CPH from MEH. (fig 1a)

Measurements were compared between the right and left side and categorized according to Keros classification (fig 1c, d) and their distributions were analyzed according to gender. Mean height of the lateral lamellar (LLH) with standard deviation were calculated. All differences in means were analyzed using standard T test. Difference in the distribution of Keros classification according to laterally and gender were tested by Fisher's exact test whichever was appropriate p-value less than 0.05 were considered significant.

The configuration of the ethmoid roof was evaluated a having straight or significant broken wing type. (fig 1b) The asymmetry of the roof was calculated in depth differences and divided into 3 categories; 1) right side deeper than left, 2) left side

Chart 1 : Technical parameter	
KV	120
mAs	91
FOV	197 mm.
Pitch	0.8
Filter	Low/contrast B135 medium smooth
Slice thickness	2 mm.
Window	2500/800

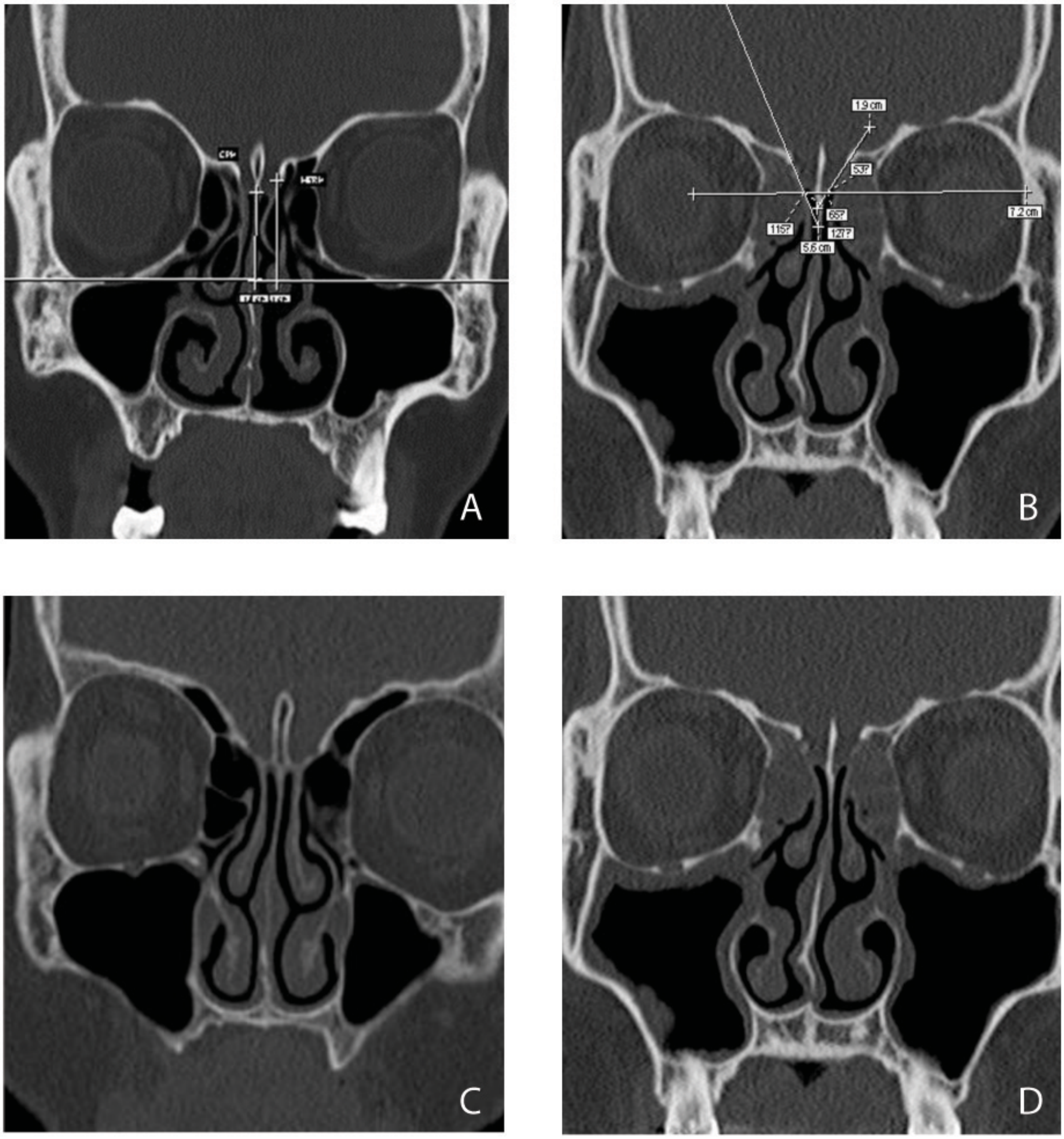

Fig 1: **a:** Measurement of the depth of the lateral lamella in a coronal paranasal sinus CT scan
b: Measurement of angulation
c: Example of Keros type 1 with angulation
d: Example of Keros type 2

deeper than right and symmetrical right and left side.

Results

CT scans of 75 patients (150 sides) were analyzed. There were 51 males (68%) and 24 females (32%). The average age of the patients was 40.91 (17-77) which of the male and female were 49.83 and 36.71 respectively.

The height of the lateral lamellar cribiform plate (LLCP) {N=150} range from 0-6 mm. The average height of LLCP was 2.15±1.29 mm and 2.16±1.35 and 2.13±1.15 mm for the right and left side respectively. [Table 1]

There were no statistic difference between the average right and left LLCP height in both men, women and overall. (p=0.243, 0.242 and 0.741). Comparison between gender, there were also no statistic difference of average of LLCP height. (p=0.078)

When the LLCP height of right and left side were compared for each individual, asymmetrical height between two sides were found in 33 cases (30.67%). The average height difference was 0.39 mm. which was no statistic difference between the gender. The distribution of the difference between two sides according to gender is presented in Table 2.

According to Keros classification, the LLCP height were classified into Keros type1 in 131 sides (87.33%) and Keros type 2 in 19 sides (12.67%). There was no Keros type 3 found in our study. No significant difference between male and female in term of Keros classification type (Fisher exact test p=0.80). The distribution and percentage values of

Table 1 Average±standard deviation of LLCP height according to gender and laterality

	Right (mm)	Left (mm)	Overall (mm)
Male	2.33±1.38	2.21±1.19	2.28ฑ1.28
Female	1.79±1.25	1.96±1.33	1.88ฑ1.28
Overall	2.16±1.35	2.13±1.15	2.15ฑ1.29

Table 2 Distribution and percentage values of the right and left LLCP height difference according to gender

Depth Difference (mm)	Male			Female			Overall		
	N (%)	Rt>Lt	Lt>Rt	N (%)	Rt>Lt	Lt>Rt	N (%)	Rt>Lt	Lt>Rt
No	34 (66.67)	-	-	18 (75.00)	-	-	52 (69.33)	-	-
1	14 (21.45)	7 (50.00)	7 (50.00)	4 (16.69)	1 (25.00)	3 (75.00)	18 (24.00)	8 (44.44)	10 (55.56)
2	3 (5.88)	3 (100.00)	0	2 (8.33)	1 (50.00)	1 (50.00)	5 (6.67)	4 (80.00)	1 (20.00)
3	0	0	0	0	0	0	0	0	0

the LLCP height according to Keros type are shown as in Table 3.

The average LLCP height of each Keros type was calculated as in Table 4. There was only statistic difference in average height of Keros type 2 between gender. ($p=0.05$)

For each individual different Keros type were seen in 3 cases (4%), 2 male and 1 female. Configuration asymmetry in the fovea ethmoidalis were found in 6 cases (8%) which one case shown bilaterally. (Table 5)

Table 3 Distribution and percentage values of the LLCP height according to Keros classification

Keros type	Right		Left		Overall
	Male (%)	Female (%)	Male (%)	Female (%)	(%)
1	42 (82.35)	22 (91.67)	46 (90.2)	21(87.5)	131 (87.3)
2	9 (17.65)	2 (8.33)	5(17.65)	3 (12.5)	19 (12.67)
3	0	0	0	0	0
Overall	51 (100)	24(100)	51 (100)	24 (100)	150 (100)

Table 4 Average height of the LLCP according to Keros classification between gender

Type	Male		Female		Both sex		Overall
	Right	Left	Right	Left	Right	Left	
1	1.90 ± 1.08	1.98 ± 0.98	1.64 ± 1.09	1.67 ± 1.15	1.81 ± 1.08	1.88 ± 1.04	1.85 ±1.055
2	4.33 ± 0.71	4.40 ± 0.55	4.00	4.00	4.28 ± 0.47	4.25 ± 0.46	4.26 ± 0.56

Table 5 Distribution and percentage of the LLCP height symmetry-asymmetry

	Male (%)	Female (%)	Overall (%)
No angulation	48 (94.12)	21 (87.5)	69 (92.00)
Right angulation	1 (1.96)	1 (4.17)	2 (2.67)
Left angulation	2 (3.92)	1 (4.17)	3 (4.00)
Bilateral angulation	-	1 (4.17)	1 (1.33)

Discussion

With advanced in ESS, CT study has been an important tool for preoperative evaluation together with the clinical examination and nasal endoscope. With CT study, determining the depth of the ethmoid roof is crucial for planning the upper limit of the dissection and providing a road map for the surgical procedure and assisting in avoidance surgical manipulation.

In anatomical study of 450 skulls by Keros, type 1 was found in 12%, type 2 in 70% and type 3 in 18 %.

As compared to Keros study, we find the difference in the distribution of the Keros type. Our study shows that Keros type 1 is the most frequent type, 89.33%, followed by type 2, 12.67%. There is no type 3 at all. Our finding is the same as Paber et al study in Philippine (109 patients) which classified 81.6% of the sides as Keros type 1 and 17.9% as type 2. Only 1 case (0.5%) was classified as type 3.Distribution and percentage of Keros type in different studies are seen in Table 6.

The average of the LLCP height in our study is 2.15 mm. The study from Philippines showed 2.11 mm.

Melani et al determined the mean LLCP height to be 5.9 mm. in subjects from Italy. Alazzawi et al found a mean height of 2.64 mm. in the study from Malaysia, China and India and Kaplanoglu et al reported a mean height of 4.92 mm. from Turkey.

Analysis the results from Table 6 and average values of LLCP height from many studies support and strengthen the hypothesis that the ethmoid roof configuration varies between populations.

Comparison between gender,our study shows no different regards to the mean LLCP height or in terms of the distribution of Keros classification. These findings are the same as Kaplanoglu et al study.

There is also no significant difference between the mean height or distribution of Keros type of the right and left side. Therefore the risk of intracranial entry through the lateral lamella during ESS is the same regardless of laterality.

About the ethmoid roof configuration, there

Table 6 Distribution and percentage of Keros classification in different studies.

	Keros type				
Study	Country	Number of sides	1 (%)	2 (%)	3 (%)
Present	Thailand	150	87.33	12.67	0
Paber et al (10)	Philippines	218	81.6	17.9	0.5
Alazzawi et al (12)	Malaysia,China, India	300	80.0	20.0	0
Elwany et al(12)	Egypt	600	42.5	56.8	1.4
Souza et al (11)	Brazil	400	26.3	73.3	0.5
Salaries et al (12)	USA	100	83.0	15.0	2.0
Keplanoglu et al (12)	Turkey	1000	13.4	76.1	10.5

are 36.7% of cases that show different in LLCP height. However there are only 8% of cases that show angulation of the ethmoid roof.

In conclusion, this study evaluates the height, classification and configuration of the ethmoid roof and analyzes the difference between gender and side. In this study, Keros type 1 is the most frequent type. Only 8% of cases showing angulation of the ehmoid roof is observed. That means there may be low risk of inadvertent intracranial entry during ESS procedure in Thai patients. However the sample size is not enough to represent Thai people. Further collection of cases is recommended. Moreover the careful pre-operative evaluation of the anatomy of each patient is still crucial for the surgeon. The LLCP height and presence of ethmoid roof asymmetry must be included in the routine description of CT reports.

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