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Comparison between Keros and Gera Classifications on Paranasal Sinuses Computed Tomography Scan at a Teaching Hospitals in Medan, Indonesia

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Abstract

Background: Functional endoscopic sinus surgery (FESS) is a surgical procedure for chronic rhinosinusitis (CRS). Keros and Gera classification can be used to evaluate the height and angle of the lateral lamella (LL) on computed tomography (CT) scan of the paranasal sinuses (PNS) which is the most dangerous area and at risk of injury during FESS. This study aimed to analyze the difference between Keros and Gera classifications on CT scans of PNS.

Methods: This study was a cross-sectional study using the results of PNS CT scans from 94 patients at Prof. Dr. Chairuddin Panusunan Lubis Universitas Sumatera Utara Hospital, Medan, Indonesia for the period January–December 2022. The Keros and Gera classification of PNS CT scan were compared based on age and gender and then analyzed using the Chi-Square test. The results were significant if the p-value <0.05.

Results: The most common type of right-sided Keros classification was Type 2 (54.3%) and left-sided was Type 1 (56%), while the most common type of right-sided and left-sided Gera classification were Type 2 (67% and 80.8%). A significant difference was found between the Keros and Gera classification types (p<0.001). The higher the Keros type did not guarantee the higher Gera type, each type of Keros could be paired with each type of Gera.

Conclusions: There is a significant difference between Keros and Gera classification on the results of PNS CT scan of patients. Keros classification alone is not enough to identify the high-risk areas at the skull base, therefore, a combination with Gera classification needs to be evaluated by a radiologist to help the clinician in planning a safer FESS.

Keywords: CT scan, Gera classification, Keros classification, paranasal sinuses

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Introduction

Sinonasal diseases, particularly chronic rhinosinusitis (CRS), are commonly encountered in the otolaryngology clinic.[1] A previous study conducted in Medan, Indonesia reported that in 2008, there were 296 patients with CRS who came for treatment to the Rhinology Division of Adam Malik Hospital Medan.[2] Functional endoscopic sinus surgery (FESS) is the standard therapy for CRS, however, there is a risk of complications, with iatrogenic cerebrospinal fluid (CSF) rhinorrhea being one of the most serious. The area most vulnerable to injury during FESS is the lateral lamella (LL), which is the thinnest bone at the anterior skull base.[3,4]

In 1962, Keros developed classification system based on the height of LL, dividing into three types, namely types 1, 2, and 3. Among these, Keros type 3 is considered the most susceptible to iatrogenic injury.[5] Although the

Keros classification is widely used, several studies have highlighted its limitations in describing the overall characteristics of LL and predicting the risk of iatrogenic injury. To address these limitations, the Gera classification was developed to assess the angle of LL and classify the lamella lateral of cribiform plate (LLCP) angles into Class I (>80 degrees, low risk), Class II (45 to 80 degrees, moderate risk), and Class III (<45 degrees, high risk).[6] Computed tomography (CT) scan of paranasal sinuses (PNS) serves as an important roadmap during FESS to avoid possible complications related to anatomy. Normal anatomy of LLCP is possible to identified on the FESS target, allowing the surgeon to be more careful in planning and using the surgical approach during FESS.[4,7]

There has been no study assessing LLCP using the Keros and Gera classification in North Sumatra, Indonesia. Therefore, this study aimed to analyze the differences in Keros and Gera classifications based on PNS CT scans at Prof. Dr. Chairuddin Panusunan Lubis Universitas Sumatera Utara Hospital, Medan, Indonesia. These findings may support better preoperative evaluation of PTLG, thereby helping to minimize the risk of iatrogenic complications during FESS.

Methods

This was a cross-sectional study using the PNS CT Scans from 94 patients aged 17 and older who underwent imaging at Prof. Dr. Chairuddin Panusunan Lubis Universitas Sumatera Utara Hospital, Medan, Indonesia between January and December 2022. Patients were included if they met the inclusion. Patients who had history of trauma, surgery, and tumors on or around the ER area, including olfactorius fossa (OF) and olfactory recessus, and the CT scans with artefacts that obscured the LL and LLCP measurements were excluded. Comorbidities such as autoimmune disease, diabetes mellitus, and malignancy outside ER area were not considered exclusion criteria due to these conditions did not significantly affect LLCP morphology. Ethical approval for this study was granted by the Ethics Committee of the Faculty of Medicine Universitas Sumatra Utara (approval number: 473/KEPK/USU/2023).

CT imaging was performed using a Philips Brilliance iCT 128-slice scanner (serial number: 302845), with a slice thickness of 3 mm and without intravenous contrast. Only scans with coronal sections deviating less than 5 degrees from the true coronal plane were included. LL and LLCP angle assessments were

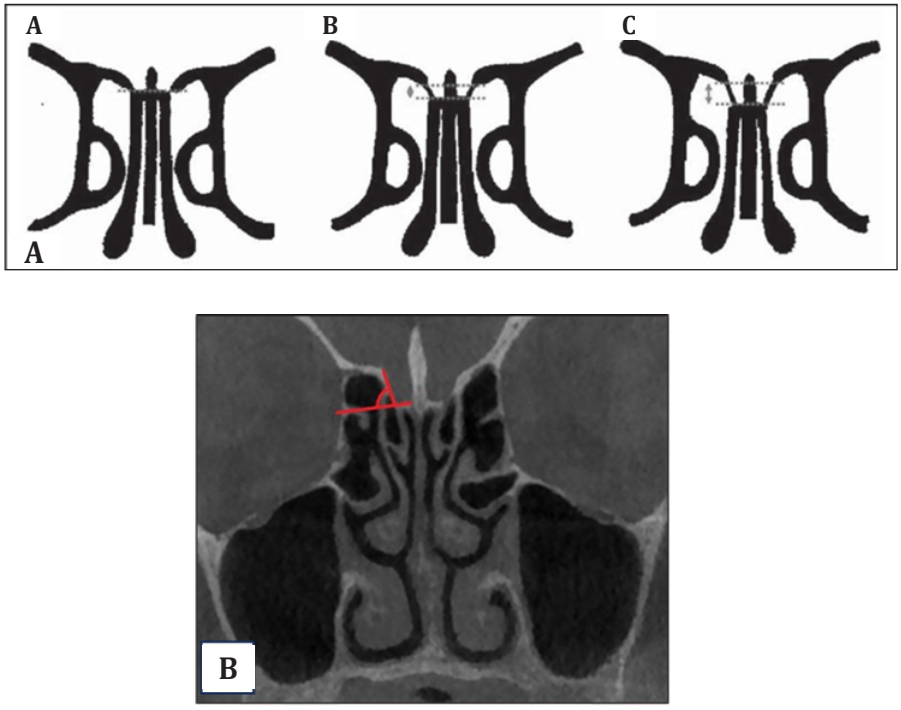

Figure 1 Measurement of Keros (A) and Gera (B) Classification.[5]

conducted using multiplanar reconstruction (MPR) viewed in DICOM format on the Picture Archiving and Communication System (PACS), using a Lenovo Yoga 7 laptop. The evaluations were conducted by a radiology resident and confirmed by a board-certified radiologist.

The height of the LL was measured on coronal bone window images using anatomical landmarks including the infraorbital foramen, the medial ethmoid roof point (MERP) that was defined as the convergence point between the ethmoid roof and cribriform plate as well as the cribriform plate (CP) point. A horizontal line connecting the medial ends of the MERP on both sides and another line intersecting the CP were drawn, and the vertical distance between these two lines was measured. Based on this distance, the LL was classified into Keros type I for heights of 1 to 4 mm, type II for 4 to 8 mm, and type III for 8 to 16 mm.

The LLCP angle was evaluated based on the Gera classification by measuring the angle between the LL and the horizontal plane of the CP. LLCP angles greater than 80 degrees were classified as Gera class I, angles between 45 and 80 degrees as class II, and angles less than 45 degrees as class III. All measurements were recorded in a standardized data sheet for further analysis. The data obtained were then analyzed using the Chi-Square test. The results were significant if the p-value <0.05.

Results

Of the 94 patients, the number of male and female patients was the same, 47 people each, while for age groups, the largest number was in the 26–45 year age group (42%) (Table 1). In the youngest age group (17–25 years), Keros type 1 was more prevalent on both the right and left sides, indicating a tendency for lower Keros types in younger individuals. In contrast, higher age groups showed a greater prevalence of Keros type 2. Regarding gender, the most common Keros type on the right side in males was type 2, observed in 35 patients (74.5%), while in females, the most common type was type 1, found in 31 patients (65.9%). On the left side, Keros type 2 was most frequent among males (29 patients, 61.7%), whereas Keros type 1 was more common in females (35 patients, 74.4%) (Table 2).

Gera type 2 was the most common classification across all age and gender groups. However, Gera type 3 appeared more frequently in the youngest age category (17–25 years), particularly on the right side and more often in females. Specifically, on the right side, 11 females (23.4%) and only 3 males (6.4%) exhibited Gera Type 3. On the left side, Gera Type 3 was found in 9 females (19.2%), and no males were classified in this type (Table 3).

As shown in Table 4, the most common

Table 1 Characteristics of Patients (n=94)

Characteristics	Mean ± Deviation	n	%
Age	38.24 ± 15.26		
17–25 years		24	25.5
26–45 years		42	44.7
46–65 years		19	20.2
>65 years		9	9.6
Gender			
Male		47	50.0
Female		47	50.0

Table 2 Characteristics of Keros Classification Type based on Age and Gender

Variable	Right Keros Type		Left Keros Type	
	1	2	1	2
Category of age (years)				
17–25	14 (58.3%)	10 (41.7%)	17 (70.8%)	7 (29.2%)
26–45	16 (38.1%)	26 (61.9%)	22 (52.4%)	20 (47.6%)
46–65	11 (57.9%)	8 (42.1%)	11 (57.9%)	8 (42.1%)
>65	2 (22.2%)	7 (77.8%)	4 (44.4%)	5 (55.6%)
Gender				
Male	12 (25.5%)	35 (74.5%)	18 (38.3%)	29 (61.7%)
Female	31 65.9%)	16 (34.1%)	35 (74.4%)	12 (25.6%)

Table 3 Characteristics of Gera Classification Type based on Age and Gender

Variable	Right Gera Type			Left Gera type		
	1	2	3	1	2	3
Category of age (years)						
17–25	3 (12.5%)	15 (62.5%)	6 (25%)	1 (4.1%)	19 (79.2%)	4 (16.7%)
26–45	10 (23.8%)	27 (64.3%)	5 (11.9%)	5 (11.9%)	35 (83.3%)	2 (4.8%)
46–65	1(5.3%)	17 (89.4%)	1 (5.3%)	2 (10.5%)	14 (73.7%)	3 (15.8%)
>65	3 (33.3%)	4 (44.5%)	2 (22.2%)	1 (11.1%)	8 (88.9%)	0 (0%)
Gender						
Male	15 (31.9%)	29 (61.7%)	3 (6.4%)	6 (12.8%)	41 (87.2%)	0 (0%)
Female	2 (4.3%)	34 (72.3%)	11 (23.4%)	3 (6.3%)	35 (74.5%)	9 (19.2%)

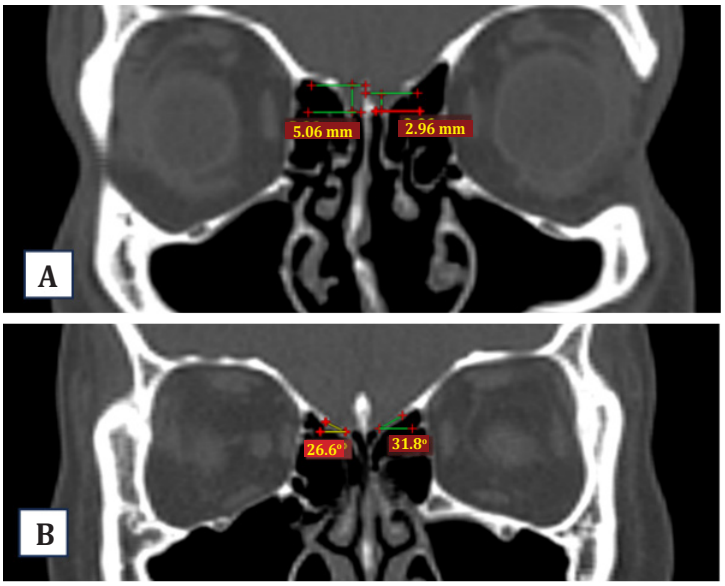

Figure 2 Measurement Result in Male (A) and Female (B) Patients

Note: Measurement result in male showed Keros type 1 on the left side and type 2 on the right side (asymmetric) (A), measurement result in female patient showed Gera type 3 on both sides (B).

combination of Keros and Gera classifications on the right side was Keros type 2 and Gera type 2 (34%). On the left side, the most frequent combination was Keros type 1 and Gera type 2 (45.7%). On the right side, 32.9% of those with Keros Type 1 also had Gera type 2, and 12.7% had Gera type 3. Among those with Keros type 2, 18% were classified as Gera type 1. On the left side, 35% of Keros type 2 cases were also Gera type 2. A small proportion of Keros type 1 on the left side corresponded to Gera type 1 (1%) and Gera type 3 (9%). Statistical analysis using the Chi-square test yielded a p-value of <0.001, indicating a significant association

Table 4 Comparative Analysis of Right and Left Side Keros with Gera

Keros Type	Gera Type			P-value
	Type 1	Type 2	Type 3	
Right				<0.001*
Type 1	0	31 (32.9%)	12 (12.7%)	
Type 2	17 (18%)	32 (34%)	2 (2%)	
Left				<0.001*
Type 1	1 (1%)	43 (45.7%)	9 (9%)	
Type 2	8 (9.5%)	33 (35%)	0	

Note: * Chi Square test

between Keros and Gera classifications on both the right and left sides.

Discussion

Chronic rhinosinusitis (CRS) is a persistent inflammation on the nasal and paranasal sinus mucosa. FESS is a common treatment for CSR but has risks of serious complications, including CSF leaks.[3,8,9] CT scan of PNS is used as a roadmap during FESS, guiding surgeons identify anatomical variations, especially LL and LLCP, since LL is the thinnest bone and the most vulnerable area during surgery.[4,7,10]

This study included 47 males and 47 females. On the right side, Keros type 2 was the most common type, whereas on the left side, Keros type 1 was most common. These findings were in accordance with Keros in 1962 which analyzed the ER of 450 cadavers. The most common type was type 2 (4–7 mm) in 70% of specimens.[5] Meanwhile, based on gender, type 2 was the most common in males, whereas females showed a higher prevalence of type 1.[5,11] This may be caused by hormonal factors on bone development. Testosterone in males induces the faster bone growth and prolonged ossification process in LL. In contrast, females may experience hyperostosis frontalis internal (HFI), influenced by progesterone and estrogen which is a natural condition that caused thickening of the frontal area of the skull which could explain the prevalence of shorter LL (type 1) in this group.[11–14]

Furthermore, based on the age category, the youngest age category (17–25 years) tended to have a lower Keros classification (type 1), compared to the older age category, which mostly showed type 2. These results are in line with studies showing that ethmoid sinus development continues until approximately 19 years of age. Differences in ethmoid anatomy are influenced by heredity, environmental factors, previous infections, and ethnicity. Additionally, pneumatization of the frontal sinus and ethmoid labyrinth varies across individuals and populations, potentially affecting LL height.[15,16]

In this study, of the Gera classification results also showed that type 2 was most common across age groups and gender, aligning with Gera's original findings.[6] However, type 3 was more frequently observed in the youngest age group and in females, particularly on the right side. This is consistent with previous research suggesting smaller LLCP angles (Gera type 3) are more common in younger patients and females.[17] Based on age, development period of the ethmoid sinus itself will end between the ages of 10 and 19 years. In the early stages of development, ER still tends to be low, so the LLCP angle will be smaller at a younger age. As age increases, dehiscence slowly occur in the LL so that the LL area becomes thin and broad, which makes the LL higher and the Gera angle increases in the older adults population, so older adults patients have a higher risk of complications than young patients undergoing FESS. This process in older adults patients is accompanied by thinning of the orbital cortical plate, which leads to orbital complications during FESS.[6,18]

Theoretically, the LLCP is the thinnest bone, with a thickness between 0.05 and 0.2 mm. The LLCP forms the weak medial side of the ethmoid roof. The LLCP angle varies even within the same individual. The contour of fovea ethmoidalis (FE) is determined by the angle of the FE joining the CP. The possibility of straight or shaped FE wings and level pneumatization of the frontal sinuses and ethmoid labyrinth also vary in different populations, even within the same individual.[17,19]

While Keros classification has been extensively studied, fewer investigations have explored LLCP angulation using Gera classification. The LLCP articulates laterally with the most medial aspect of the frontal orbital plate. The angle of LLCP and FE articulations is defined by FO of the intracranial, as well as the ER and depth of the olfactory recess of the nose. The depth of the FO is directly related to the length and degree of angulation, the deeper the FO, the more vertical the LLCP. As the depth of the vertical moment of the LL descends, the angle formed by the ER decreases. This would increase the risk of iatrogenic injury in LLCP. [12,13,17,19]

This study focused on comparative analysis between Keros and Gera classification. Significant differences were found between Keros and Gera. Similar findings were reported by another study which attributed such differences to sample size.[18] Other contributing factors include ethnic variations, measurement techniques and the slice position used during CT imaging.[17,19–21] Another study observed that LL height was negatively correlated with LLCP angle, suggesting that subjects with a more prominent anterior skull base (small Gera) in the coronal plane could have a higher LL.[10] The Gera classification system can be more informative than the Keros classification in the analysis of LLCP, which is more often associated with iatrogenic CSF leaks. A more prominent of the anterior skull base in the

coronal plane may predispose to injury to the medial skull base during more medial ethmoid cell dissection and frontal sinus surgery. During FESS, the instruments are close to the LLCP, and the dissection is done from posterior to anterior.[6,22]

Limitations of this study include the adults-only population (aged 17 years and above) and lack of consideration for ethnicity or comorbidities that could affect ethmoid development. Future studies could expand by including pediatric populations, considering broader demographic variables, and employing longitudinal or cohort designs to evaluate complication risks more comprehensively.

In conclusions, the Gera classification complements the Keros classification in evaluating LLCP anatomy on CT scans of PNS. The prevalence of type 2 Keros is more prevalent in males and older age groups. Meanwhile, type 1 Keros is more common in females and younger individuals. For Gera classification, type 2 is predominant across most groups. Each Keros type may correspond with multiple types of Gera. A statistically significant difference is found between the Keros and Gera classification types. Using both classification in preoperative evaluation may help reduce the risk of complications during FESS.

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