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RESEARCH

PARANASAL SINUS ANATOMICAL DIFFERENCES IN ELDERLY PATIENTS

Abstract

Introduction: Endonasal endoscopic sinus surgeries performed on elderly patients can be challenging due to anatomical variations, and can be studied using preoperative computed tomography. The aim of the present study was to evaluate paranasal sinus anatomical differences in elderly patients compared to a younger control group.

Materials and Methods: We retrospectively evaluated paranasal computed tomography scans of 47 elderly patients (>65 years old) (Elderly group) and 47 younger patients (Control group) for midfacial skeletal size (interzygomatic buttress distance, nasion-basion distance), anatomical variations, dimensions, and paranasal sinus volumes.

Results: The mean age of the Elderly group was 69.89 years (65- 81 years) and the mean age of the Control group was 33.15 years (20-49 years). There was no significant difference in midfacial size between the two groups. The prevalence of Keros Type III olfactory fossa was significantly higher in the Elderly group than in the Control group ($p<0.05$). The Elderly group had a significantly lower mean maxillary sinus volume ($p<0.01$) and mean anteroposterior diameter of the sphenoid sinus ($p<0.01$) compared to the Control group. Furthermore, there was no significant difference in the maxillary sinus volume between the elderly edentulous and dentulous patients($p>0.05$).

Conclusion: Elderly patients have more Keros Type III olfactory fossa, which confers a higher risk of iatrogenic cerebrospinal fluid leakage during endoscopic sinus surgery. The preoperative detailed evaluation of computed tomography scans of elderly patients should include, but not be limited to, the ethmoid roof for deep olfactory fossa, and the sphenoid sinus for its narrow anterioposterior dimention.

Keywords: Aged; Paranasal Sinuses; Endoscopy; Anatomy; Nose; Nasal Cavity; Computed Tomography.

INTRODUCTION

Paranal sinus development continues after birth, and changes during life. The maxillary sinus is the first to develop, and pneumatization of maxillary sinus continues after birth. The volume of the maxillary sinus increases until the age of 20 years, after which the volume decreases (1). The maxillary sinus volume is thought to be influenced by age, sex, tooth loss, height, and weight (2, 3). Although the paranasal sinus volume and skeletal size may change with these parameters, the midfacial skeletal size can be used as a reference of the skeletal size in studies assessing its volume (1, 4).

Sphenoid sinus aeration begins from birth, until the late 30's (5). After this, the volume of the sphenoid sinus begins to decrease (5). The frontal sinus can only be detected on radiologic images after the age of three, and is highly variable due to different pneumatization (6). Although individual frontal sinus anatomical variations exist, patients older than 60 years of age are suggested to have a higher frontal sinus volume due to osseous resorption (7). This process in elderly patients is accompanied by thinning of the cortical orbital plate, which can lead to orbital complications during endoscopic frontal surgery (6).

The ethmoid skull base consists of the fovea etmoidalis, an extension of the frontal bone, and the cribriform plate. These two structures converge at the lateral lamella of the cribriform plate, a fragile area known to be a common site for iatrogenic skull-base injury during endonasal endoscopic surgery (8). The Keros classification stages the depth of the cribriform fossa (Type I: 1–3.9 mm, Type II: 4–7.9 mm, Type III ≥8 mm), and suggests that a deeper cribriform fossa is more susceptible to iatrogenic cerebrospinal fluid (CSF) leakage during endoscopic sinus surgery (9, 10).

Elderly patients have a higher risk of complications than younger patients undergoing endoscopic sinus surgery (11). Thus, studying the anatomy of the paranasal sinus using computed tomography (CT) can promote endonasal endoscopic surgical safety. In addition to individual anatomical variations, analyzing the differences in a group of patients can increase our understanding of different susceptibilities in elderly patients during an endonasal surgery. Therefore, the aim of the present study was to evaluate paranasal sinus anatomical differences in elderly patients compared to a young control group.

MATERIALS AND METHODS

This study was carried out with the approval of the ethics committee. In this study, we retrospectively evaluated paranasal CT scans of 47 elderly patients (>65 years old) (Elderly group) from our radiology database. The control group included paranasal CT scans of 47 young patients (<50 years old). The CT scans for all patients were taken in the outpatient clinic for chronic nasal blockage. Patients with nasal polyposis, chronic sinusitis, previous paranasal sinus operations, tumors, fracture, and severe nasal septal deviations that could affect the paranasal anatomy were excluded from the study.

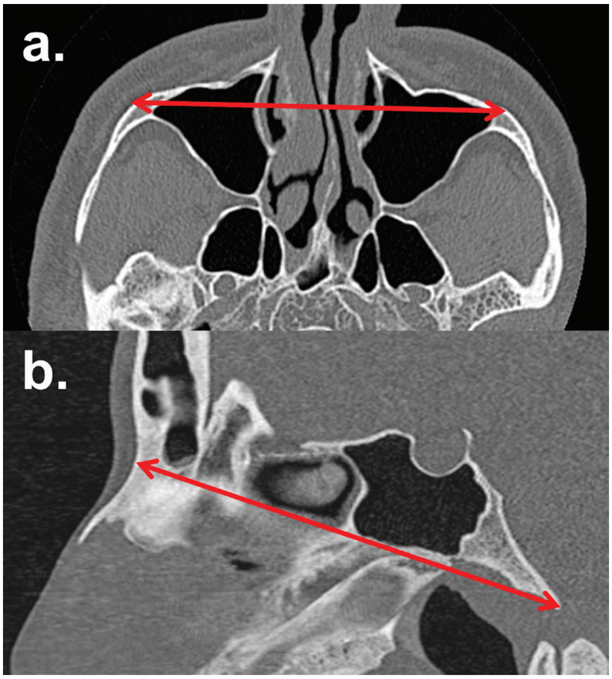
All patients were screened on a 16-detector spiral CT scanner (Toshiba Alexion, Tokyo, Japan) with 120 kV and 120 mA parameters. The coronal and sagittal reformat and reconstruction images were obtained from axial scans taken at 3 mm slice thickness from the patient in a supine position with their head on the scanning table. All images were analyzed by an expert radiologist using the OsiriX MD software (v8.0, Pixmeo, Geneva, Switzerland). In order to eliminate variability caused by patient orientation, the images were standardized in 3 orthogonal planes. Images of the two groups were examined for the following surgery-related anatomical variations;

1) Patients with at least one upper molar tooth were considered as dentulous, and patients with no teeth in the upper jaw were considered as edentulous.

2) Interzygomatic buttress distance (IBD) and nasi-

on-basion distance (NBD): IBD and NBD, modified from the method by Waitzman et al. (4), were adopted as an index for midfacial skeletal size. IBD was defined as the distance between the anterolateral corners of each zygomatic buttress in the axial CT scan. NBD was defined as the distance between the nasion and basion in the saggittal CT scan (Figure 1).

Figure 1. Midfacial dimensions. (a.) Interzygomatic buttress distance and (b.) nasion-basion distance.



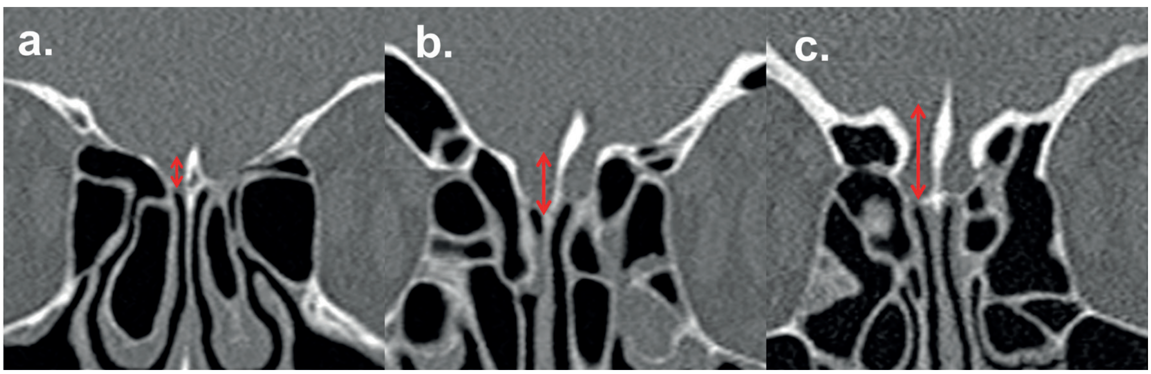
3) Keros classification: The depth of the cribriform plate was measured at the largest vertical height of the olfactory fossa in the coronal plane on both sides. Type I was 1–3.9 mm, type II was 4–7.9 mm, and type III was ≥8 mm (9). (Figure 2)

4) Ethmoid roof angle (ERA): We measured the ERA by measuring the angle between the midline corresponding with the crista galli, and the line drawn along the fovea ethmoidalis. This was measured at the coronal section that was posterior to the anterior most view of the superior turbinate on both sides (12).

5) Orbital floor angle (OFA): OFA was measured as the angle between the lamina papyracea and the orbital floor, measured in the coronal CT that depicted the hiatus semilunaris superioris (12).

6) Pneumatized middle turbinate: Pneumatization of the middle turbinate may include cells in the vertical lamella (an interlamellar cell) or in the inferior bulbous portion. It was evaluated on the coronal plane and classified as 0 (none), 1 (unilateral), and 2 (bilateral).

Figure 2. Keros classifications for the heigth of the olfactory fossa; a.Type I: 1–3.9 mm, b. Type II: 4–7.9 mm, c. Type III ≥8 mm



7) Pneumatized superior turbinate: This was evaluated on the coronal plane, and classified as 0 (none), 1 (unilateral), and 2 (bilateral).

8) Paradoxical middle turbinate: A curvature of the middle turbinate such that the convex surface was lateral rather than medial. This variation was considered to be present if paradoxical curvature was seen in at least two consecutive levels (13). It was evaluated on the coronal plane, and classified as 0 (none), 1 (unilateral), and 2 (bilateral).

9) Pneumatized crista galli: The crista galli sits anteriorly in the midline above the cribriform plates. Crista galli pneumatization was noted from either the left or right frontal sinuses on the coronal plane.

10) Pneumatized vomer: Pneumatization of the vomer was noted in sinuses on the coronal plane.

11) Agger nasi cell: Cells in an anterior ethmoid air chamber below the frontal sinus, which was intimately related to frontonasal recess, reaching the lacrimal fossa inferolaterally and anterolaterally arched by the nasal bones (13, 14) was evaluated on 3 planes, and classified as 0 (none), 1 (unilateral), and 2 (bilateral).

12) Haller cell: Any air cell located in the roof of the maxillary sinus or inferior portion of the lamina papyracea below the ethmoid bulla (14) was evaluated on 3 planes, and classified into 0 (none), 1 (unilateral), and 2 (bilateral).

13) Onodi cell: A posterior ethmoid air cell that pneumatized into the region normally occupied by the sphenoid sinus, this posterior ethmoid cell extends superior and lateral to the sphenoid sinus (15) was evaluated on 3 planes, and classified as0 (none), 1 (unilateral), and 2 (bilateral).

15) Accessory maxillary ostium: This was evaluated on the coronal plane and classified as0 (none), 1 (unilateral), and 2 (bilateral).

16) Maxillary floor-nasal floor distance: The parallel line drawn to the nasal floor and the maximum distance of the maxillary sinus floor to this line were measured on the coronal plane.

17) Dimensions and volumes of the paranasal sinuses: The maximum anteroposterior (AP), transverse (TRV) and craniocaudal (CC) diameters of the maxillary, ethmoid, and sphenoid sinuses were measured in 3 planes. The diameters were presented in millimeters (mm). The estimated volume of the paranasal sinus was calculated by the ellipsoid volume formula: $\pi/6 \times TRVdiameter \times APdiameter \times CCdiameter$. The estimated volumes were presented in cubic millimeters (mm^3).

Statistical analyses were performed using the SPSS 21.0 program (SPSS, Inc., Chicago, Illinois). For qualitative data analysis, Pearson chi-square test was used. For the quantitative data analysis, Kolmogorov-Smirnov test was used for compatibility with normal distribution. T-test and ANOVA test were used for independent groups for data that fit the normal distribution. Mann-Whitney U test and Kruskal-Wallis test were used for data that did not fit the normal distribution. In all statistical analyses, $p \leq 0.05$ was considered significant.

RESULTS

The mean age of the Elderly group was 69.89 (65-81 years) and the mean age of the Control group was 33.15 (20-49 years). There was no significant difference in the gender distribution between the Elderly group (26 males/ 21 females) and the Control group (21 males/ 26 females) ($p>0.05$). Paranasal anatomical variations are summarized in Table 1. There was no significant difference in paranasal anatomival variations between the two groups.

The Keros Classification results are summarized in Table 2. The prevalence of Keros Type III olfactory fossa was significantly higher in the Elderly group than in the Control group ($p<0.05$).

Table 1. Paranasal anatomical variations between the Elderly and Control groups.

		Elderly Group		Control Group		p
		n	%	n	%	
Pneumatized middle turbinate	absent	25	53,2	18	38,3	0.116
	unilateral	9	19,1	18	38,3	
	bilateral	13	27,7	11	23,4	
Pneumatized superior turbinate	absent	29	61,7	21	44,7	0.251
	unilateral	12	25,5	18	38,3	
	bilateral	6	12,8	8	17,0	
Paradoxical middle turbinate	absent	36	76,6	34	72,3	0.857
	unilateral	9	19,1	10	21,3	
	bilateral	2	4,3	3	6,4	
Pneumatized crista galli	absent	41	87,2	44	93,6	0.485
	present	6	12,8	3	6,4	
Pneumatized vomer	absent	30	63,8	27	57,4	0.527
	present	17	36,2	20	42,6	
Ager nasi cell	absent	8	17,0	2	4,3	0.099
	unilateral	11	23,4	9	19,1	
	bilateral	28	59,6	36	76,6	
Haller cell	absent	38	80,9	33	70,2	0.475
	unilateral	5	10,6	9	19,1	
	bilateral	4	8,5	5	10,6	
Onodi cell	absent	35	74,5	28	59,6	0.1342
	unilateral	8	17,0	8	17,0	
	bilateral	4	8,5	11	23,4	
Axessory maxillary ostium	absent	21	44,7	23	48,9	0.597
	unilateral	11	23,4	8	17,0	
	bilateral	15	31,9	16	34,0	

Midfacial dimensions, paranasal sinus volumes, and dimensions of the groups are summarized in Table 3. There was no significant difference in IBD and NBD between the two groups. The mean maxillary sinus volume was significantly lower in the Elderly group compared to the Control group. Three subjects in the Elderly group and one subject in the Control group had frontal sinus agenesis, and were excluded from the frontal sinus analysis. There were no significant differences in the

Table 2. Keros classifications of the Elderly and Control groups for the height of the olfactory fossa.

		Elderly Group		Control Group		p
		n	%	n	%	
Keros Type Left Side	I	8	17,0	14	29,8	0.004
	II	23	48,9	29	61,7	
	III	16	34,0	4	8,5	
Keros Type Right Side	I	10	21,3	17	36,2	0.045
	II	22	46,8	24	51,1	
	III	15	31,9	6	12,8	

Type I: 1–3.9 mm, Type II: 4–7.9 mm, Type III ≥8 mm

Table 3. Midfacial dimensions, paranasal sinus dimensions (mm) and volumes (mm^3) of the Elderly and Control groups.

		Elderly Group		Control Group		p
		Mean	Standart Deviation	Mean	Standart Deviation	
Midfacial Dimentions	IBD	106,7	5,93	105,74	5,61	0.232
	NBD	99,36	4,97	99,79	5,12	0.250
Maxillary Sinus Right	Volume	18,31	5,78	22,2	6,4	0.003
	AP	37,12	3,1	39,14	3,38	0.003
	TR	24,61	5,54	27,14	4,12	0.017
	CC	36,36	7,91	39,4	5,32	0.041
Maxillary Sinus Left	Volume	18,45	6,1	23,11	6,49	0.001
	AP	37,2	3,44	39,53	3,34	0.001
	TR	25,15	3,76	27,36	4,22	0.010
	CC	36,88	5,96	40,39	5,27	0.003
Frontal Sinus	Volume	16,21	4,56	13,38	5,25	0.070
	AP	17,41	10,14	14	5,25	0.050
	TR	56,69	18,64	54,23	17,8	0.532
	CC	27,84	9,39	29,23	8,39	0.459
Sphenoid Sinus	Volume	12,68	6,88	13,45	4,57	0.097
	AP	26,32	5,28	30,18	4,7	0.001
	TR	36,34	7,89	36,98	7,46	0.494
		23,69	4,91	22,61	3,22	0.501

IBD: Interzygomatic buttress distance, NBD: Nasion-basion distance, AP: Anterior-Posterior distance, TR: Transverse distance, CC: Craniocaudal distance frontal sinus and sphenoid sinus volumes between the groups. The anteroposterior diameter of the sphenoid sinus was significantly lower in Elderly group compared to The Control group.

There was no significant difference in the maxillary floor-nasal floor distance between the Elderly group (6.9 ± 4.22) and the Control group (6.64 ± 3.38) ($p>0.05$). There was no significant difference in the ERA between the Elderly group (Right mean: 74.21 ± 11.41, Left mean: 79.78 ± 14.11) and the Control group (Right mean: 71.58 ± 8.64, Left mean: 75.43 ± 12.98) ($p>0.05$). Furthermore, there was no significant difference in the OFA between the Elderly group (Right mean: 114.21 ± 15.87, Left mean: 120.46 ± 7.16) and the Control group (Right mean: 117.10 ± 4.93, Left mean: 120.18 ± 5.44) ($p>0.05$).

The Elderly group was further divided into edentulous (n=23, 12 males/11 females) and dentulous (n=24, 14 males/10 females) groups. There was no significant difference in the maxillary sinus volumes between the edentulous and dentulous elderly group ($p>0.05$). All patients in the control group were dentulous.

DISCUSSION

As the life expectancy increases, the number of endonasal endoscopic surgeries performed on elderly patients increases (11, 16). Ramadan et al. reported that elderly patients undergoing endoscopic sinus surgeries had significantly more complications, such as CSF leakage (11). In this study, we found that the Keros classification for the olfactory fossa depth significantly differed between the Elderly group and Control patients. Elderly patients had more Keros Type III olfactory fossa comparing to young patients, which increases risk of iatrogenic skull base trauma during endonasal endoscopic surgery. Osseous resorption has been postulated to cause the higher frontal sinus volumes seen in elderly patients (6). Osseous resorption may not only affect ethmoid sinuses leading to a deeper olfactory fossa in elderly patients, but also lead to a fragile and vulnerable ethmoid skull base.

Yonetsu et al. studied the volume of the sphenoid sinus using CT images and found that the volume reduced after the age of 30 years (5). We found that the volume of the sphenoid sinus was lower in the Elderly group; however, this was not statistically significant. However, the mean anteroposterior diameter of the sphenoid sinus was significantly lower in the Elderly group. This was considered to be an important finding since a lower anteroposterior diameter can lead to iatrogenic trauma in the sphenoid sinus during endonasal endoscopic surgery. Iatrogenic sphenoid sinus injury may happen during endonasal sendoscopic surgeries performed on elderly patients. Emanuelli et al. reported cases of iatrogenic sphenoid sinus injury leading to CSF leakage in elderly patients (17).

Takahashi et al. studied maxillary sinus volumes in elderly cadavers and found that the maxillary sinus tends to be smaller when a greater number of molars are missing (3). Ariji et al. studied the maxillary sinus volume using CT scans and found that there was no difference between the dentate and edentulous group between the age 50 to 79 (1). In our study, we found no significant difference in the mean maxillary sinus volume between dentulous and edentulous elderly patients. Dedeoglu et al. studied maxillary sinus variations in elderly patients using cone-beam CTs and found that the accessory maxillary ostium was increased in elderly patients in than younger patients (18). We found no significant differences in the accessory maxillary ostium between the two groups.

Fatu et al. studied plain radiographs to evaluate the frontal sinus related to age and reported an increased frontal sinus area in elderly patients, which is thought to result from osseous resorption (6). This process in elderly patients is accompanied by thinning of the cortical orbital plate, which can lead to orbital complications during endoscopic frontal surgery (6). In our study, although not statistically significant, we found that the mean volume of frontal sinus of elderly was higher.

Our study has some limitations worth mentioning. The volume of the paranasal sinuses may be influenced by height and weight, which we failed to assess (3). However, we measured the midfacial skeletal size as a reference and compared this between the groups (1, 4). We found no significant difference, which suggests that the changes observed in the elderly were not due to differences in skeletal sizes between the two groups. Second, we did not calculate the exact three-dimensional volumes, but instead calculated volumes using the dimensions of individual sinuses. Furthermore, we did not measure the left and right frontal sinus dimensions separately, which may lead to overestimation of the calculated volumes after using the formula.

Preventing complications during endoscopic endonasal surgeries requires an elaborate study of the anatomical variations observed on the preoperative CT scan. Preoperative CT evaluation of elderly patients should include, but not be limited to, the ethmoid roof for deep olfactory fossa, the sphenoid sinus for its narrow anterioposterior distance, and the frontal recess for orbital wall thinning. Endonasal endoscopic surgeons should be cautious at these vulnerable regions when operating on elderly patients.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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