

# Morphometric examination of the paranasal sinuses and mastoid air cells using computed tomography

Sacide Karakas, PhD; Ahmet Kavakli, MD, PhD

**BACKGROUND:** The paranasal sinuses and mastoid air cells vary considerably in size and shape from person to person. The main structures are pneumatic. In this study, we investigated the relationship between right and left sides and evaluated the volume changes according to age and sex.

**METHODS:** Of all patients attending the radiology department, 91 cases without paranasal sinuses and mastoid air cells pathology (i.e., inflammation, operation or trauma) were selected for evaluation. Axial computed tomography (CT) scans were obtained for both paranasal sinuses and temporal bones. In all scans, the volumes of each area (maxillary sinus, frontal sinus, sphenoid sinus and mastoid air cell) were calculated and analyzed statistically.

**RESULTS:** The volumes of paranasal sinuses and mastoid air cells increased with age and women had a lower mean volume. There was a positive correlation between right-left and ipsilateral structures (paranasal sinuses and mastoid air cells).

**CONCLUSIONS:** These results are helpful in understanding the normal and pathological conditions of the paranasal sinuses and the mastoid air cells.

*From the Department of Anatomy of Adnan Menderes University, Aydin, Turkey, and the Department of Anatomy of Firat University, School of Medicine, Elazig, Turkey*

*Correspondence:*  
*Ahmet Kavakli, MD*  
*Department of Anatomy*  
*Firat University School of Medicine*  
*23119 Elazig, Turkey*  
*E-mail: kavaklia@yahoo.com*

*Accepted for publication:*  
*July 2004*

Ann Saudi Med 2005; 25(1): 41-45

Paranasal sinus anatomy is complex and rather variable from person to person. Significant differences in structure between the two sides may also exist in the same person. Therefore, a detailed knowledge of the anatomy of the sinuses is critical in performing procedures such as functional endoscopic sinus surgery.<sup>1,2</sup>

The main characteristics of these structures are pneumatic, and the initiation and process of pneumatization differ from person to person.<sup>2-7</sup> Genetic diseases, environmental conditions and past infections may affect this process.<sup>4,6,8</sup> There is still no consensus about when pneumatization begins and how it develops in temporal bone.<sup>8</sup> Diamant and other investigators first studied the mastoid air cells on a scientific and methodological basis and first used this information in practice.<sup>6,9,10-14</sup> Several studies on the pneumatization of temporal bone have been published.<sup>8,11,15</sup> In their book, Graney et al<sup>15</sup> reported several researchers' results on measurement of paranasal sinuses at and after birth. Until the use of computed tomography (CT) by Haunsfield for diagnosis in 1972, x-ray films were used for the measurement of area, volume and shape of paranasal sinuses and the mastoid air cells.<sup>10,12-14</sup> Since then the use of CT has been common in studies.<sup>11,12-17-23</sup> CT scans and MR images illustrate the range of normal radiologic findings associated with the developmental process, with emphasis placed on the types of findings that, although normal, create potential interpretation difficulties.<sup>23</sup> In this study, we have investigated the volumes obtained from CT images of paranasal sinuses and the mastoid air cells in terms of the following features: (i) differences based on age groups, (ii) the relationship between paranasal sinuses and the mastoid air cells based on age and sex, (iii) differences between the right and left sides in both sexes. The results will be helpful in understanding normal and pathological conditions of the paranasal sinuses and the mastoid air cells.

## Methods

This study was based on a retrospective review of the paranasal sinuses and temporal bone CT scans 91 cases (47 men and 44 women) selected from 317 patients with temporal bone

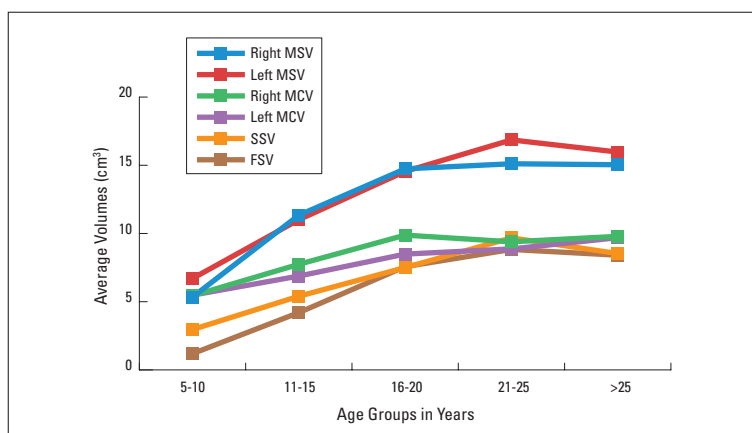


Figure 1. Comparison of the volumes of paranasal sinuses and mastoid air cells based on age groups in men.

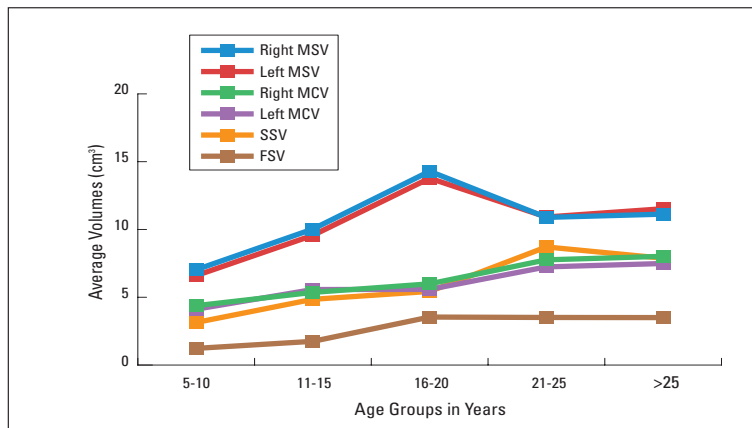


Figure 2. Comparison of the volumes of paranasal sinuses and mastoid air cells based on age groups in women.

and paranasal sinuses CT analysis (General Electric Prospeed Helical CT, Milwaukee, USA) because there was no history of ear disease in any of the subjects and clinical examination revealed no ear, nose or throat abnormality. Persons with congenitally absent sinuses were excluded. Subjects were divided into five-year age groups (total 5 groups) starting at the age of 5 years.<sup>10</sup> For symmetry and to prevent rotation, the head was fixed face up in the supine and neutral position for each CT analysis. The scan mode was helical. After lateral scenograms, examinations consisted of 2-mm axial cross sections (120 kv, 160 mA) for the temporal bone and 5-mm axial cross sections (120 kv, 160 mA) for the paranasal sinuses.<sup>24</sup> All cross sections were parallel to the infraorbital line. While the cross sectional series for temporal bone were taken

upstream of the superior semicircular channel to the basal curl of the cochlea as far as the mastoid air cells, the series for paranasal sinuses were taken from the base of the maxillary sinus to the end of the frontal sinus.

The areas of each tomographic slice were determined by carefully tracing their outlines using the area measurement function of the CT scanner. For consistency and reliability, the same person carried out CT scanning twice for each section, and a mean value was obtained. The volume of CT in each section was calculated by multiplying the area (cm<sup>2</sup>) by the slice thickness (0.2 cm). By summing all volumes of every slice based on the Cavalieri principle for volume calculation, the total volume of areas was expressed in cubic centimeters as mean  $\pm$ SD.<sup>25</sup>

SPSS for Windows 11.0 was used for the statistical assessment. Descriptive statistics are provided as the mean (X) with standard deviation (SD). Analytic assessment was done by the Student *t*-test and Kruskal-Wallis test and a *P* value less than 0.05 accepted as statistically significant.

## Results

The 91 cases (47 men and 44 women) ranged in age from 5 years to 55 years. Average volumes of the paranasal sinuses and mastoid air cells by age group are shown in Table 1 for men and in Table 2 for women. In men, the highest averages for all paranasal sinuses were mostly in the 21 to 25 year age group. The highest averages for the right and left MCV were in the 16 to 20 and >25 year age groups, respectively. In women, the highest averages for right, left and total MSV were in the 16 to 20 year age group, while the highest averages for right, left and total MCV were in the >25 year age group. Average volumes for the paranasal sinuses and mastoid air cells for all men and women are shown in Table 3. It is evident that the volumes of paranasal sinuses and mastoid air cells increase with age in both sexes.

In the statistical comparison between sexes, there was no significant difference for right MSV and SSV. Significant differences were detected for other parameters. The strongest correlation and most significant differences were observed in the right MSV-left MSV and in the right MCV-left MCV ( $r=0.822$ ;  $P<0.001$ ) in both sexes (Table 4).

## Discussion

The volumes of the paranasal sinuses and mastoid air cells are reported to increase with age.<sup>2,5,8</sup> Our results

**Table 1.** Average volumes (cm<sup>3</sup>) of paranasal sinuses and mastoid air cells based on age groups in men.

	5-10 years old		11-15 years old		16-20 years old		21-25 years old		>25 years old		P value
	n	Mean±SD	n	Mean±SD	n	Mean±SD	n	Mean±SD	n	Mean±SD	
Right MSV	9	5.34 ± 0.56	10	11.34 ± 3.100	8	14.74 ± 5.79	10	15.11 ± 4.95	10	15.04 ± 5.20	0.000
Left MSV	9	6.70 ± 1.10	10	11.01 ± 2.54	8	14.55 ± 4.72	10	16.86 ± 5.77	10	15.97 ± 6.65	0.000
Right MCV	9	5.44 ± 1.30	10	7.74 ± 2.11	6	9.88 ± 5.95	10	9.39 ± 5.53	10	9.79 ± 2.82	0.021
Left MCV	9	5.48 ± 1.36	10	6.88 ± 2.85	8	8.49 ± 6.47	10	8.87 ± 5.77	10	9.69 ± 2.96	0.112
SSV		2.96 ± 2.53	10	5.40 ± 1.96	8	7.50 ± 3.21	10	9.68 ± 2.62	9	8.53 ± 4.19	0.001
FSV		1.19 ± 0.69	9	4.20 ± 3.98	8	7.57 ± 5.72	10	8.83 ± 4.46	10	8.41 ± 4.03	0.008
Total MSV	9	12.04 ± 2.22	10	22.43 ± 5.50	8	29.30 ± 10.25	10	31.97 ± 8.97	10	30.98 ± 11.41	0.000
Total MCV	9	10.89 ± 2.53	10	14.62 ± 4.74	8	15.91 ± 13.24	10	17.27 ± 9.66	10	19.48 ± 5.62	0.092

MSV, maxillar sinus volume; MCV, mastoid air cell volume; SSV, sphenoid sinus volume; FSV, frontal sinus volume.

**Table 2.** Average volumes (cm<sup>3</sup>) of paranasal sinuses and mastoid air cells based on age groups in women.

	5-10 years old		11-15 years old		16-20 years old		21-25 years old		>25 years old		P value
	n	Mean±SD	n	Mean±SD	n	Mean±SD	n	Mean±SD	n	Mean±SD	
Right MSV	9	7.03 ± 2.02	9	10.03 ± 4.41	9	14.29 ± 3.42	8	10.89 ± 4.50	9	11.13 ± 4.52	0.012
Left MSV	9	6.60 ± 2.25	9	9.57 ± 4.48	9	13.78 ± 3.41	8	10.92 ± 3.63	9	11.53 ± 5.45	0.011
Right MCV	8	4.38 ± 1.35	9	5.36 ± 1.83	7	5.99 ± 2.74	8	7.76 ± 3.96	9	8.02 ± 3.84	0.106
Left MCV	9	4.12 ± 1.22	9	5.57 ± 2.08	7	5.58 ± 2.80	8	7.24 ± 3.59	9	7.49 ± 2.99	0.076
SSV	8	3.14 ± 2.30	9	4.85 ± 1.09	9	5.43 ± 2.59	8	8.71 ± 2.44	9	7.88 ± 2.99	0.001
FSV	4	1.23 ± 0.29	8	1.75 ± 1.42	9	3.54 ± 2.25	7	3.51 ± 3.11	8	3.50 ± 2.41	0.046
Total MSV	9	13.63 ± 4.16	9	19.62 ± 8.74	9	28.08 ± 6.68	8	21.81 ± 7.83	9	22.66 ± 9.75	0.010
Total MCV	9	8.11 ± 2.67	9	10.9 ± 3.64	7	11.56 ± 5.17	8	15.00 ± 6.99	9	15.52 ± 6.71	0.044

MSV, maxillar sinus volume; MCV, mastoid air cell volume; SSV, sphenoid sinus volume; FSV, frontal sinus volume.

**Table 3.** Mean volumes (cm<sup>3</sup>) of paranasal sinuses and mastoid air cells.

	All subjects (n=91)		Men (n=47)		Women (n=44)		Men vs. Women	
	n	Mean±SD	n	Mean±SD	n	Mean±SD	t	P
Right MSV	91	11.54 ± 5.10	47	12.36 ± 5.62	44	10.67 ± 4.39	1.592	0.115
Left MSV	91	11.82 ± 5.38	47	13.09 ± 5.85	44	10.47 ± 5.51	2.379	0.020
Right MCV	86	7.40 ± 3.73	45	8.39 ± 3.1	41	6.33 ± 3.14	2.641	0.010
Left MCV	89	7.00 ± 3.80	47	7.91 ± 4.32	42	5.99 ± 2.81	2.442	0.017
SSV	89	6.43 ± 3.41	46	6.83 ± 3.73	43	6.00 ± 3.02	1.143	0.256
FSV	76	4.97 ± 4.31	40	6.86 ± 4.83	36	2.87 ± 2.29	4.516	0.000
Total MSV	91	23.37 ± 10.11	47	15.72 ± 8.06	42	12.19 ± 5.75	2.071	0.041
Total MCV	89	14.05 ± 7.24	47	25.46 ± 10.94	44	21.14 ± 8.74	2.355	0.021

MSV, maxillar sinus volume; MCV, mastoid air cell volume; SSV, sphenoid sinus volume; FSV, frontal sinus volume.

**Table 4.** Correlation constants (r) of paranasal sinus and mastoid air cell parameters in men and women.

	Men		Women	
	r	P	r	P
Right MSV-Left MSV	0.822	0.0001	0.922	0.0001
Right MSV-Right MCV	0.243	0.107	0.248	0.118
Right MSV-Left MCV	0.266	0.077	0.252	0.108
Right MCV-Left MCV	0.935	0.0001	0.835	0.000
Right MSV-SSV	0.407	0.005	0.372	0.014
Left MSV-SSV	0.438	0.002	0.374	0.013
Right MSV-FSV	0.339	0.033	0.374	0.025
Left MSV-FSV	0.386	0.014	0.330	0.049
Total MCV-Right MSV	0.138	0.355	0.272	0.081
Total MCV-Left MSV	0.227	0.125	0.314*	0.043
Total MCV- SSV	0.398	0.006	0.427	0.005
Total MCV- FSV	0.228	0.156	0.497	0.003
FSV-SSV	0.306	0.058	0.229	0.186
Total MSV- SSV	0.441	0.002	0.381	0.012
Total MSV- FSV	0.388	0.013	0.361	0.030

MSV, maxillar sinus volume; MCV, mastoid air cell volume; SSV, sphenoid sinus volume; FSV, frontal sinus volume.

also show that the volumes of paranasal sinuses and mastoid air cells increase regularly with age in both sexes. Diamant reported that development of sinus pneumatization ends at the age of 10 years in women and at the age of 15 years in men.<sup>9</sup> Rubensohn agreed with this conclusion, stating that development happens in a regular manner with an average growth of 1.5 cm<sup>2</sup> in women and 1 cm<sup>2</sup> in men.<sup>12</sup> Based on his observation, Rubensohn also suggested that the development of mastoid air cells was different at different ages and sexes during childhood.<sup>12</sup> On the other hand, Viraspongse et al, in their study of 100 cases, reported that pneumatization of temporal bone did not change significantly with sex and age.<sup>8</sup> Our study was similar to Rubensohn's study for age and sex differences. The reason for the difference between the Rubensohn and Viraspongse et al's studies could be the environmental conditions suggested by Wittmaack<sup>33</sup> and genetic contributions to pneumatization proposed by Cheatele.<sup>34</sup>

The mean MCV in our study was 14.05±7.24 cm<sup>3</sup> compared with a mean MCV of 10.43±6.66 cm<sup>3</sup>, 12.22±9.79 cm<sup>3</sup>, 8.4±3.6 cm<sup>3</sup> and 6 cm<sup>3</sup> in Park et al,<sup>26</sup> Fleshberg et al,<sup>11</sup> Colhoun et al,<sup>21</sup> and Isono et al's 19

studies, respectively. In addition, while the mean values for the right and left MCV in our study were 7.40±3.73 cm<sup>3</sup> and 7.00±3.80 cm<sup>3</sup> (Table 3), compared with 6.08±2.52 cm<sup>3</sup> in the right and 6.19±2.93 cm<sup>3</sup> in the left in Pata et al.<sup>27</sup> Surprisingly, while Isono et al<sup>19</sup> and Luntz et al<sup>28</sup> observed that there were no differences between right and left MCVs in males and females and while Tos et al<sup>6</sup> also reported that MCV remained the same in right and left sides, there were significant differences for right and left MCV between the sexes in our study ( $P=0.010$  for the right and  $P=0.017$  for the left (Table 3)). Also, as seen Table 1, while there was a significant difference for right MCV among the different age groups in men, the same difference was not present for left MCV in men ( $P=0.021$  vs.  $P=0.112$ ). Furthermore, no statistically significant difference was found among the different age groups for right and left MCV in women ( $P=0.106$  vs.  $P=0.076$ ).

In their examination of the paranasal sinuses, Arijji et al<sup>29</sup> and Ikeda et al<sup>30</sup> reported that the volumes of the paranasal sinuses increased up to the age of 20 years, but then decreased. Similarly, Schatz et al<sup>31</sup> observed that the ethmoid, maxillary and sphenoid sinuses exhibited an increase in volume for a period up to 15 years, afterwards maintaining similar values. In comparison with the volumes of the paranasal sinuses in our and some other investigators' studies, interesting points were as follows:

For the SSV, Antoniadis et al.<sup>7</sup> reported that the sphenoid sinus started to develop very quickly after the age of 3 and spread back towards the sella turcica at around the age of 7 years, reaching adult form at around the age of 12.<sup>2</sup> Amedee et al<sup>2</sup> and Yonetsu et al<sup>24</sup> reported a maximum average SSV of 7.5 cm<sup>3</sup> and 8.2±0.5 cm<sup>3</sup>, respectively. Additionally, Yonetsu et al<sup>24</sup> observed in the same study that thereafter, the volume decreased gradually, with the average volume in the seventh decade of life being 71% of the maximum level. In our study, SSV increased in both sexes up to 25 years (SSV=8.71±2.44 cm<sup>3</sup>) and decreased after the age of 25.

For the MSV, Colhoun et al<sup>21</sup> and Amedee et al<sup>2</sup> reported a mean MSV of 20.05±9.2 cm<sup>3</sup> and 14.75 cm<sup>3</sup>, respectively. In their study, Arijji et al<sup>29</sup> observed no significant sex differences and reported a correlation in MSV between the two sides. Similarly, Nowak et al<sup>32</sup> reported that the sinus maxillaries of the left side were greater than that of the right side in both male and female patients, and that the sinus maxillaries were greater in female patients than in male patients. Thomas and Raman<sup>17</sup> determined

that there was a significant relationship among MSV, FSV and MCV as well as a good correlation between FSV and MSV on the same side. Based on their observations, they suggested that paranasal sinuses and mastoid air cells might develop by different processes. In our study, men had a greater difference in MSV than women among the different age groups (Tables 1 and 2).

For the FSV, there is limited information in the literature. Amedee et al<sup>2</sup> reported FSVs of 6-7 cm<sup>3</sup>. In our study, the mean FSV was 4.79±4.31cm<sup>3</sup> and the mean values of the sexes were strikingly different ( $P=0.0001$ , Table 3).

In our study, there was a direct proportional relationship between age and the volume increase in both sexes as well as a difference in the average volumes between sexes (women's lower than men's). In a comparison of men and women, while the highest volume increase for paranasal sinuses (MSV, SSV and FSV) in men appeared in the 21 to 25 year age group, the highest volume for MCV occurred in the

>25 year group. On the other hand, while the highest volume increase for MSV and FSV in women was observed in the 16 to 20 year age group, the highest volume was seen for MCV and SSV in the 21 to 25 year age group.

In conclusion, the volumes of the paranasal sinuses and mastoid air cells increase regularly with age in both sexes. The strongest correlation for these volume increases was observed in right-left MSV and in right-left MCV. In the light of these results, it would be useful to have more details for volumes of paranasal sinuses and mastoid air cells by CT scanning. The results will be helpful in understanding normal and pathological conditions of the paranasal sinuses and the mastoid air cells.

### Acknowledgement

We thank Dr. Kaya Sarac in Department of Radiology for his assistance in the taking of CT images. Also, we thank to Dr. Yuksel Yildiz for his assistance in the preparation of manuscript.

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