Published in final edited form as:

Int J Pediatr Otorhinolaryngol. 2012 January ; 76(1): 137–141. doi:10.1016/j.ijporl.2011.10.021.

Mastoid Geometry in a Cross-Section of Humans from Infancy through Early Adulthood with a Confirmed History of Otitis Media

J. Douglas Swarts, PhD¹, Sean Foley, BA², Cuneyt M. Alper, MD¹, and William J. Doyle, PhD¹

¹Department of Otolaryngology, Children's Hospital of Pittsburgh and the University of Pittsburgh, School of Medicine.

²Department of Anthropology, University of Pittsburgh.

Abstract

Objective—This study describes the changes in mastoid air cell system (MACS) geometry with age in ears with a history of otitis media (OM), without (GR-I) or with (GR-II) middle ear fluid on the CT scan.

Methods—Thirty-seven (74 MACSs) CT scans were selected to approximate 4 MACSs/year between 1 and 18 years. For each MACS, the volume, surface area and surface area/volume ratio were reconstructed using standard procedures. Correlation analysis was used to define the left-right relatedness for the geometric parameters, and regression analysis was used to determine the effect of age on those parameters for each group.

Results—Twenty scans were from female and 17 from males. Fluid was observed in 12 left, 4 right and 10 bilateral MACSs. The MACS volume and surface area of GR-I increased with age, were significantly greater than those for age-matched MACSs in GR-II, but show large variability. Those measures in GR-II were independent of age and a large percentage of these MACS volumes was < 5 ml. The surface-area/volume ratio for MACSs in both groups was independent of age and group assignment. The left-right correlations for the three geometric parameters of the MACS were significant for all MACS in the two groups, and for bilateral MACS concordant for group assignment. The left-right correlations for surface area and volume were not significant for bilateral MACSs discordant for group assignment.

Conclusions—These results suggest that: the growth of MACS volume and surface area is genetically programmed but that this is disrupted by long-lasting OM; the effect of OM on MACS growth may depend on the duration and timing of the disease, and the MACS surface area/volume ratio does not explain the effect of MACS volume on the rate of gas exchange between middle ear and blood.

© 2011 Elsevier Ireland Ltd. All rights reserved.

Address correspondence to: J. Douglas Swarts, PhD, 3420 5th Ave, Oakland Medical Bldg, Room 118, Pittsburgh Pa, 15213, USA, Phone: +1 412 692-3598, FAX: +1 412 692-7555, dswarts@pitt.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

CONFLICT OF INTEREST STATEMENT

None of the authors has a conflict of interest associated with this manuscript.

Keywords

Mastoid Geometry; Growth; Otitis Media; CT scans

INTRODUCTION

The mastoid air cell system (MACS) is a highly cellular posterior extension of the middle ear that is continuous in the air-phase with the tympanum. While the function of the MACS is not well established (1), a large number of studies show that MACS volume is inversely related to the frequency of certain pathological conditions of the middle ear including cholesteatoma and otitis media (2–6). To explain this relationship, researchers have suggested that the MACS is a middle ear pressure-buffer (2), a rate limiter of middle ear pressure change (1) and/or a source of gas that stabilizes middle ear pressure (7–9).

Significant left-right correlations for MACS geometry measured as volume, surface area and the surface area/volume ratio in adults with a wide range of MACS volumes were documented, previously (10) and similar results were reported for children without a history of otitis media over a wide age range (11). These bilateral symmetries suggest a genetic component for MACS geometry as was proposed for MACS volume by Diamant (12). However, it is a matter of debate if persons with constitutively small mastoid volumes are “at risk” for middle ear disease or if the presence of middle ear disease stunts MACS development (6, 13–18).

Recently, Csakanyi and colleagues reconstructed MACS volume and surface area from CT scans in a cross-sectional sample of 40 children aged 2.5 to 17.5 years without a significant history of otitis media and in 56 children aged 2.0 to 17.0 years with both a history of otitis media and concurrent evidence of that disease (11). They described a linear increase in MACS volume and MACS surface area to age 7 years, a plateau between 7 and 13 years and then an increase to age 18 years for the disease-free group, but no age-related change in those measures for the group with concurrent otitis media. They also reported that a MACS volume of 5 ml was a reasonable discriminator for the two groups; with the frequency of MACS volumes <5 ml being much higher in the otitis media group.

While clearly important with respect to demonstrating a difference in MACS volume and surface area between groups of children with and without otitis media over a wide age range, the study by Csakanyi and colleagues does not directly address whether MACS volume is stunted by otitis media or if smaller MACS volumes predispose to otitis media since children in the otitis media group all had extant disease (11). In the present study, CT scans for a group of children between the ages 1.5 and 18.2 years with a history of otitis media and without or with observable fluid in the middle ear were analyzed and the MACS volume, surface area and surface area/volume ratios were calculated. The hypotheses tested were: 1) MACS volume and surface area would be less at all ages in those children with extant fluid when compared to those with no observable fluid and 2) the left-right correlations for the geometric parameters of the MACS would be higher in children with the same bilateral disease presentation when compared to those with bilaterally discordant disease presentations.

METHODS

This study reconstructed and measured MACS volume, surface area and the surface area/volume ratio from CT scans for a cross-sectional sample of infants, children and adolescents with a history of otitis media by chart review and without middle ear fluid (GR-I) or with

(GR-II) observable middle ear fluid on the CT scan. A set of CT scans was selected from the collection at the University of Pittsburgh and the medical charts of the subjects were reviewed for any noted abnormalities in the CT scan (other than middle ear fluid) and for a history of otitis media by one of the investigators (CMA). The CT was rejected for inclusion in the study if anatomical abnormalities were detected or if no history of otitis media was recorded in the subject's clinical chart. An attempt was made to obtain 2 scans (4 MACSs)/year between the ages of 1 and 18 years. The study was reviewed and approved by the University of Pittsburgh IRB.

The chosen CT scans included the middle ear and bilateral MACSs and were acquired in the transverse plane using a GE LightSpeed VCT system (General Electric Health Care). The images were obtained using a field of view which included both temporal bones (range 138 to 180 mm) with a 512×512 matrix. The resolution averaged over the entire sample was 0.032 cm per pixel with a slice thickness of 0.063 cm. From each CT scan, the complete set of transverse images through the bilateral MACSs (superior to inferior) was used for the reconstructions. Using Image J software (<http://rsbweb.nih.gov/ij/>), these sections were imported, and the left and right MACSs and tympanums were identified, segmented out and analyzed. For each MACS, the perimeter and area of all air-cells were calculated, corrected with the appropriate calibration factor, and summed across images. These sums were multiplied by the section interval to yield MACS surface area (cm^2) and volume (ml). This procedure is essentially identical to that used previously to measure MACS volume, surface area and the surface area/volume ratio in adult subjects over a wide range of MACS volumes (10, 19).

Each ME was examined for the presence/absence of extant middle ear fluid. One of the primary challenges of automatically extracting the area and perimeter of air-cells from CT images of MACSs with middle ear fluid is the lack of contrast between the fluid and surrounding tissues (eg. muscle, brain; see Figure 1A) which is not an issue when the cells are air-filled. We addressed this problem by first eliminating tissues peripheral to the temporal bone. This was accomplished by creating a temporal bone mask which when applied to the original image stack excised the surrounding tissues (Figure 1B). Then, the contrast in the resulting image was increased interactively to produce images in which fluid intensity was shifted toward the value for air (Figure 1C). The resulting image stack was converted to binary information (Figure 1D) and analyzed in the same manner as for those middle ears without evidence of fluid.

All data were entered into Microsoft Excel for analysis. For each individual MACS, the measured surface area was divided by the measured volume to determine the surface area/volume ratio for that MACS and these values were averaged across left and right MACSs in the two groups. For the three primary geometric parameters, MACS volume, surface area and surface area/volume ratio, the Pearson Product Moment Correlation (r) was used to determine the relationships between surface area and volume for the left and right MACSs, separately, the left-right values for all MACSs in the population, and the left-right values for MACSs in three subgroups defined as bilateral normal, bilateral fluid and unilateral fluid. Linear regression analysis was used to characterize the relationships between each geometric parameter and age for: 1) left and right MACSs, 2) sex of the subjects from whom the MACSs were obtained, and 3) all MACSs in the two groups. The significance of the slope for the regression equations was compared to a value of 0 using a two-tailed, Student's t test evaluated at $\alpha=0.05$ and the regression line fit was estimated by the Pearson Product Moment Correlation coefficient. For GR-I and GR-II, we also calculated the percent of MACS volumes in a younger (0.5–8 years) and older age group (8+ years) that were below the critical value of 5 ml described by Csakanyi and colleagues as a threshold for extant otitis media (11). Whether these percentages were significantly different was evaluated

using a chi-square test. No corrections for multiple comparisons were done. All analyses were done using the NCSS 2007 statistical program (Kaysville, Utah). The format average $\pm$ standard deviation is used to summarize the data.

RESULTS

The CT scans (74 MACSs) of 37 subjects were included in the data analyses. Twenty scans were from female and 17 from male subjects. The average age for the population was 9.8 ± 5.3 (range=0.5 to 18.1, median=10.4) years. Extant fluid was observed unilaterally in 16 subjects (12 left, 4 right) and 10 subjects bilaterally.. Both MACS of 11 subjects were judged to be free of fluid.

Age, volume, surface area and the surface area/volume ratio for each MACS assigned to GR-I or GR-II were averaged, yielding values of 10.84 ± 4.76 and 8.61 ± 5.62 years ($t=1.82$, $p=0.07$); 7.92 ± 4.51 and 5.30 ± 3.46 ml ($t=2.90$, $P<0.01$); 116.20 ± 64.38 and 74.36 ± 53.56 cm² ($t=3.02$, $p<0.01$), and 14.80 ± 2.75 and 14.03 ± 2.99 /cm ($t=1.01$, $p=0.31$), respectively. Note that the average surface area divided by the average volume is not equal to the average of the individual surface area/volume ratios.

For the entire population, the left and right MACS volumes were highly correlated with their respective surface areas ($r=0.94$, $p<0.01$; $r=0.96$, $p<0.01$). The right versus left MACS volumes ($r=0.71$, $p<0.01$), surface areas ($r=0.75$, $p<0.01$) and surface area/volume ratios ($r=0.76$, $p<0.01$) were significantly correlated. The population of individuals was subdivided into MACSs with no observable fluid bilaterally ($n=11$), unilateral fluid ($n=16$) and bilateral fluid ($n=10$) and the right versus left correlation coefficients were calculated for each geometric parameter by subgroup. The left versus right correlation coefficients for those three groups were: 0.68 ($p=.02$), 0.32 ($p=0.23$) and 0.95 ($P<0.01$) for MACS volume; 0.84 ($p<0.01$), 0.35 ($p=0.18$) and 0.97 ($p<0.01$) for surface area and 0.79 ($p<0.01$), 0.68 ($p<0.01$) and 0.83 ($p<0.01$) for the surface area/volume ratio, respectively. Of note is the smaller and non-significant left-right correlations for MACS volumes and surface areas of the group with unilateral fluid when compared to the other two bilaterally concordant groups.

The Table reports the results of the regression equations for the geometric parameters as a function of age for left and right MACSs, for MACSs from female and male subjects and for MACSs in GR-I and GR-II. The slopes of the regression lines for volume and surface area, but not the surface area/volume ratio, with respect to age were significantly different from a value of 0 for left and right MACSs, for MACS from males and females and for MACSs in GR-I. In contrast, these slopes were not significantly different from 0 for MACSs in GR-II. None of the slopes relating the surface area/volume ratio to age was significantly different from 0/cm.

Figure 2 shows the left and right volumes (a), surface areas (b) and the surface area/volume ratios (c) as a function of age for MACSs in GR-I and GR-II. For left and right MACSs in GR-I, volume showed a shallow increase to age 8 years followed by a more pronounced increase with a high variability between 9 and 18 years of age. For left and right MACSs in GR-II., with the exception of two outliers (left and right MACSs from the same subject; 9.2 years, 18.2 ml and 9.2 years, 13.7 ml), the relationship between volume and age was relatively flat varying about an average value of 4.8 ml. For both groups, surface area showed a similar age relationship as that for volume, but the left and right surface area/volume ratios for MACSs were independent of age.

The overall percent of MACS volumes less than or equal to 5 ml in the 0.5 to 8 year and the >8 year age groups were 72% and 24%, respectively ($p=0.01$). The percent of left and right MACS volumes less than or equal to 5 ml in the 0.5 to 8 year and the >8 year age groups

were 75% and 69% ($p=0.72$) and 24% and 24% ($p=1.0$), respectively. The percent of MACS volumes less than or equal to 5 ml in GR-I and GR-II was 82% and 67% ($p=0.72$) for the lower age group and 11% and 47% ($p=0.05$) in the upper age group, respectively.

DISCUSSION

Using CT based methods, one previous cross-sectional study evaluated the change in MACS geometry over a wide age range for groups of subjects with and without a history of otitis media (11). Specifically, Csakanyi and colleagues reconstructed MACS geometry for 40 individuals aged 2.5 to 17.5 years without a significant history of middle ear disease (no middle ear effusion in last 3 months and no more than 3 AOM episodes in life) and for 56 individuals aged 2.0 to 17.0 years with a history of otitis media as indicated by having at least 1 tympanostomy tube and documented otitis media at the time of CT imaging. They reported significant left-right correlations for all MACS parameters measured in both groups; larger left-right differences in MACS volume and surface area for the group with concurrent otitis media when compared to the control group, a significant increase in MACS volume and surface area with age for the control group, a relatively constant and significantly lesser volume and surface area as a function of age in the group with concurrent otitis media, and no relationship between the surface area/volume ratio and age for either group. From their results, they suggested that a MACS volume of <5 ml was a critical threshold for identifying individuals with “intractable” otitis media.

The present study differed from that of Csakanyi and colleagues in that our comparison groups were individual MACSs at different ages with a confirmed history of otitis media with or without extant middle ear fluid on the CT. The results showed that these two groups could be discriminated based on the MACS volume and surface area, especially at later ages, but not on the surface area/volume ratio. Specifically, there was no significant relationship between age and either MACS volume or surface area for the group with concurrent middle ear fluid, a significant age-related increase in those parameters for the group with a history of otitis media without concurrent middle ear fluid, and a statistically significant average difference in these MACS parameters between the groups. In the older age group with a history of otitis media but no extant middle ear fluid, MACS volume and surface area were highly variable, and many of the data points at those ages were similar to those for the control group reported by Csakanyi and colleagues (11). In older but not younger subjects, the cutoff for MACS volumes <5 ml was a reasonable discriminator of those MACS with concurrent middle ear fluid (<0.5 ml) when compared to those with a past history of otitis media but no middle ear fluid.

Small MACS volumes have been related to a susceptibility to middle ear diseases (3–6), but the mechanism is not well defined. For example, small MACS may predispose to otologic diseases or otologic diseases could stunt the growth of the MACS (6, 13–16, 18). The results for our study combined with those reported by Csakanyi and colleagues suggest that the two mechanisms are not mutually exclusive.

For bilateral structures, a high correlation between measures for the two sides (bilateral symmetry) is indicative of a significant genetic contribution while low correlations between those measures (bilateral asymmetry) is indicative of a predominant environmental contribution to the measured structure (20). Our data and those from other studies document a high left-right correlation for all parameters of MACS geometry when the condition of the left and right MACS is similar (10, 11) supporting a genetic component to these measures. However, the observed lower correlations and bilateral asymmetries for subjects with MACS discordant for disease group membership suggests that otitis media (or other factors?) can disrupt this genetically programmed expression.

Our data also suggest that transient insults to the MACS are not necessarily detrimental to the final volume of the MACS. Specially, if we assume that those individuals with concurrent middle ear fluid had persistent otitis media until the time of observation while those without concurrent middle fluid had disease that resolved at an unknown time before the measurements were done, then the wide variability in MACS volume noted for the older ages in the group with a history of otitis media but no extant fluid can be explained by differences in the extent and timing of the otitis media episodes.

Previous studies suggest that the surface area/volume ratio for the MACS and tympanum is one contributor to the rate of gas volume exchange across the middle ear mucosa under certain specified conditions (18) and therefore affects the middle ear pressure balance during periods between Eustachian tube openings. In that regard, it is interesting that surface area/volume ratio for MACS is independent of age, middle ear status and of the volume of adult MACS over a wide range of values (10, 19). Specifically, the average value of that ratio calculated for our study of MACS without and with extant fluid was 14.1 and 13.5/cm, and for two studies on different populations of adults over a wide range of MACS volumes reported by Park and colleagues and by Swarts and colleagues was 17.1/cm and 15.9/cm, respectively (10, 19). Unfortunately, Csakanyi and colleagues did not report these measurements for either the control or otitis media groups and, as mentioned, those ratios cannot be reconstructed from the averages of the surface areas and volumes presented in their Table I (11). These results suggest that, as discussed previously, this ratio alone cannot explain the differences in the rate of transmucosal gas exchange for middle ears with large and small MACS volumes (18).

In summary, the results of this cross-sectional study show that MACS volume and surface area for middle ears with a history of otitis media and concurrent effusion are relatively independent of age and that a large percentage of the volumes (especially in the older age groups) for these MACS is < 5 ml. In contrast, these measures for middle ears with a history of otitis media but without concurrent effusion increase with age, are significantly greater than those for age-matched MACS in the comparison group, but show significant variability. In general, the left-right correlations for the three geometric parameters of the MACS are correlated, but for surface area and volume, these correlations are not significant for bilateral MACS discordant for group assignment. The surface-area/volume ratio for the MACS is constant under all evaluated conditions. These results suggest that: 1) the growth of MACS volume and surface area is genetically programmed but that this is disrupted by long-lasting otitis media, 2) the effect of otitis media on the growth of the MACS may depend on the extent and duration of the disease state, and 3) the surface area/volume ratio is not the main determinant of the previously measured effect of MACS volume on the rate of gas exchange between middle ear and blood.

Acknowledgments

We thank the members of the Radiology Department for their assistance with retrieval of the CT scans used in the present study.

Supported in part by a grant from the National Institutes of Health (DC007667)

REFERENCES

1. Doyle WJ. The mastoid as a functional rate-limiter of middle ear pressure change. *Int J Pediatr Otorhinolaryngol.* 2007 Mar; 71(3):393–402. [PubMed: 17174408]
2. Sade J. The correlation of middle ear aeration with mastoid pneumatization. The mastoid as a pressure buffer. *Eur Arch Otorhinolaryngol.* 1992; 249(6):301–304. [PubMed: 1418937]

3. Sade J, Fuchs C. Secretory otitis media in adults: I. The role of mastoid pneumatization as a risk factor. *Ann Otol Rhinol Laryngol*. 1996 Aug; 105(8):643–647. [PubMed: 8712636]
4. Sade J, Fuchs C. Secretory otitis media in adults: II. The role of mastoid pneumatization as a prognostic factor. *Ann Otol Rhinol Laryngol*. 1997 Jan; 106(1):37–40. [PubMed: 9006359]
5. Lesinskas E. Factors affecting the results of nonsurgical treatment of secretory otitis media in adults. *Auris Nasus Larynx*. 2003 Feb; 30(1):7–14. [PubMed: 12589843]
6. Valtonen HJ, Dietz A, Qvarnberg YH, Nuutinen J. Development of mastoid air cell system in children treated with ventilation tubes for early-onset otitis media: a prospective radiographic 5-year follow-up study. *Laryngoscope*. 2005 Feb; 115(2):268–273. [PubMed: 15689748]
7. Takahashi H, Honjo I, Naito Y, et al. Gas exchange function through the mastoid mucosa in ears after surgery. *Laryngoscope*. 1997 Aug; 107(8):1117–1121. [PubMed: 9261018]
8. Miura M, Takahashi H, Honjo I, Hasebe S, Tanabe M. Influence of the gas exchange function through the middle ear mucosa on the development of sniff-induced middle ear diseases. *Laryngoscope*. 1998 May; 108(5):683–686. [PubMed: 9591546]
9. Sade J. Hyperectasis: the hyperinflated tympanic membrane: the middle ear as an actively controlled system. *Otol Neurotol*. 2001 Mar; 22(2):133–139. [PubMed: 11300258]
10. Swarts JD, Doyle BM, Doyle WJ. Relationship between surface area and volume of the mastoid air cell system in adult humans. *J Laryngol Otol*. Firstview. Jan.5:1–5.
11. Csakanyi Z, Katona G, Josvai E, Mohos F, Sziklai I. Volume and surface of the mastoid cell system in otitis media with effusion in children: a case-control study by three-dimensional reconstruction of computed tomographic images. *Otol Neurotol*. 2011 Jan; 32(1):64–70. [PubMed: 21068691]
12. Diamant M. Mastoid Pneumatization and Normal Curve Distribution. *Acta Otolaryngol*. 1965 Jul–Aug; 60:167–174. [PubMed: 14337952]
13. Aoki K, Esaki S, Honda Y, Tos M. Effect of middle ear infection on pneumatization and growth of the mastoid process. An experimental study in pigs. *Acta Otolaryngol*. 1990 Nov–Dec; 110(5–6):399–409. [PubMed: 2284915]
14. Ikarashi F, Nakano Y, Okura T. The relationship between the degree of chronic middle ear inflammation and tympanic bulla pneumatization in the pig as animal model. *Eur Arch Otorhinolaryngol*. 1994; 251(2):100–104. [PubMed: 8024755]
15. Tos M. Mastoid pneumatization. A critical analysis of the hereditary theory. *Acta Otolaryngol*. 1982 Jul–Aug; 94(1–2):73–80. [PubMed: 7124391]
16. Tos M, Stangerup SE. Mastoid pneumatization in secretory otitis. Further support for the environmental theory. *Acta Otolaryngol*. 1984 Jul–Aug; 98(1–2):110–118. [PubMed: 6540511]
17. Tos M, Stangerup SE, Andreassen UK. Size of the mastoid air cells and otitis media. *Ann Otol Rhinol Laryngol*. 1985 Jul–Aug; 94(4 Pt 1):386–392. [PubMed: 4040726]
18. Swarts JD, Cullen Doyle BM, Alper CM, Doyle WJ. Surface area-volume relationships for the mastoid air cell system and tympanum in adult humans: Implications for mastoid function. *Acta Otolaryngol*. 2010 Nov; 130(11):1230–1236. [PubMed: 20450279]
19. Park MS, Yoo SH, Lee DH. Measurement of surface area in human mastoid air cell system. *J Laryngol Otol*. 2000 Feb; 114(2):93–96. [PubMed: 10748822]
20. Siegel MI, Doyle WJ. The differential effects of prenatal and postnatal audiogenic stress on fluctuating dental asymmetry. *J Exp Zool*. 1975 Feb; 191(2):211–214. [PubMed: 1113068]

Figure 1.

Illustration of segmenting procedure for isolating MACS air-cells from middle ear effusion and other tissues. (a) original image of temporal bone, (b) image following masking of temporal bone, (c) interactive contrast enhancement to reduce middle ear effusion intensity toward that of air and (d) binary image used for data extraction.

2A

2B

Figure 2.

The distribution of (a) volume, (b) surface area and (c) the ratio of surface area to volume with respect to the age of the subject at the time of the CT scan. Circles represent left ears and squares represent right ears. Filled symbols are the values for ears with extant middle ear fluid. The thick and thin lines are the solutions of the linear regression equations for MACSs without and with fluid, respectively.

TABLE 1

The Sample Size (N), Intercept, Slope, Correlation Coefficient (r), 2-tailed Student's t (t-value) and Significance (p-level) for the Linear Relationship between the Volume, Surface Area and the Surface Area/Volume Ratio and age for Left and Right MACSs, MACSs from Males and Females and MACSs from Middle Ears with a History of Otitis Media but without (GR-I) and with (GR-II) extant fluid

Parameter	N	Variable	Intercept	Slope	R	t-value	p-level
Volume (ml)	37	Left	3.86	0.27	0.33	2.05	0.05
	37	Right	3.97	0.29	0.38	2.41	0.02
Surface Area (cm ²)	37	Left	53.38	4.00	0.33	2.10	0.04
	37	Right	54.84	4.56	0.39	2.50	0.02
SA/V (/cm)	37	Left	13.56	0.06	0.12	0.72	0.48
	37	Right	13.84	0.09	0.15	0.91	0.37
Volume (ml)	40	Female	3.67	0.31	0.33	2.15	0.04
	34	Male	4.17	0.25	0.40	2.44	0.02
Surface Area (cm ²)	40	Female	50.55	4.78	0.37	2.42	0.02
	34	Male	57.53	3.80	0.36	2.19	0.04
SA/V (/cm)	40	Female	13.74	0.12	0.19	1.21	0.23
	34	Male	13.50	0.04	0.09	0.52	0.60
Volume (ml)	38	GR-I	3.34	0.42	0.45	2.99	0.01
	36	GR-II	4.45	0.10	0.16	0.95	0.35
Surface Area (cm ²)	38	GR-I	45.60	6.51	0.48	3.29	<0.01
	36	GR-II	62.32	1.40	0.15	0.87	0.39
SA/V (/cm)	38	GR-I	14.07	0.07	0.12	0.70	0.49
	36	GR-II	13.54	0.06	0.11	0.63	0.53