Normative standards for nasal cross-sectional areas by race as measured by acoustic rhinometry

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Acoustic rhinometry evaluates the geometry of the nasal cavity with acoustic reflections and provides information about nasal cross-sectional area and nasal volume within a given distance. Variations in internal nasal diameters have attracted increased interest since the advent of endoscopic surgical techniques. Race is known to be one of the most important factors affecting the nasal structure. In this study, we evaluated 106 healthy adult volunteers with acoustic rhinometry to determine internal nasal diameters and volumes and obtained normative data for four racial/ethnic groups. The data were analyzed with regard to race, sex, height, and weight. All measurements were made before and after the application of a topical nasal decongestant so that the effects of the nasal cycle were eliminated by decongestion. (Otolaryngol Head Neck Surg 1998;119:389-93.)

Acoustic rhinometry (AR) evaluates the geometry of the nasal cavity with acoustic reflections and provides information about nasal cross-sectional area (CSA) and nasal volume within a given distance into the nasal cavity. The AR device used in this study generates a sound pulse from a sound generator with a peak sound pressure level of 146 dB and 50 μsec duration, which propagates in a tube and enters the nasal cavity through a nosepiece. The incident and reflected signals are measured by a microphone in the sound tube, and the corresponding CSAs and volumes are calculated. Acoustic rhinometry is a noninvasive test that is easily done in a relatively short time, and minimal patient cooperation is needed.

Grymer et al.[1] and Hilberg et al.[2] introduced the technique in normal subjects. AR is sensitive to changes in the nasal mucosa, including the phases of the nasal cycle,[3] to nasal allergen challenge,[4] and to the effects of topical decongestants. It accurately reflects area and volume changes within a given distance, and its performance is not affected by pressure and flow. AR has been validated for its accuracy in CT scan and MRI studies for examination of the nasal anatomy.[5,6]

In this study, we used AR in 106 normal adults in an attempt to define normal ranges for nasal CSAs and volumes with respect to sex and race. To our knowledge, this is the first study reporting AR ranges on the basis of these parameters. The normal ranges should provide a basis for the evaluation of pathologic or experimental conditions.

METHODS AND MATERIAL

One hundred six healthy adults were recruited by local billboard and newspaper advertisements and enrolled as paid volunteers with the approval of the University of Chicago institutional review board, and informed written consent was obtained. Inclusion criteria were as follows: absence of obvious nasal deformity, septal deviation, prior trauma, nasal operations, history of allergic rhinitis, nasal breathing problems, nasal polyps, use of nasal drops or steroids, recent or recurrent upper respiratory infections, or other significant health problems. A history was obtained followed by an ear, nose, and throat examination for assessment of the subjects' eligibility. Selection and inclusion of subjects was not based on sex or race. The recruitment of subjects was continued for 2 years, and all eligible subjects were included. Evaluation was done after data collection was terminated. The demographic information for the subject group is presented in Table 1.

A two-microphone acoustic rhinometer (Hood Laboratories, Pembroke, Mass.) was used for the evaluation of the nasal cavity. An external nasal adapter was selected for proper fit, and a thin bead layer of ointment (Lubriderm) was applied, which made an acoustically tight seal between the nostril and the nasal adapter. Care was taken not to obstruct the orifices with ointment or to deform the nose during test-

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Table 1. Demographic data

	n	Mean and range		
		Age (yr)	Height (in)	Weight (lb)
Asian female	12	24 (19-39)	64.2 (59-67)	130.4 (97-180)
Asian male	12	24.2 (18-42)	68.7 (65-75)	160.9 (120-220)
Black female	10	25.6 (18-48)	66.6 (63-73)	152.2 (124-220)
Black male	12	31.3 (20-49)	68.7 (60-73)	168.4 (135-215)
White female	25	25.1 (18-57)	65.2 (60-71)	133.4 (105-165)
White male	28	23.4 (18-38)	70.21 (68-75)	166 (130-196)
Hispanic female	3	27 (20-40)	65 (62-69)	178.3 (150-235)
Hispanic male	4	32.3 (21-40)	67 (61-71)	160.5 (136-200)
Total	106			

Table 2. Mean CSAs, standard deviations, and range (minimum-maximum)

	CSA 1			CSA 2			CSA 3		
	Asian	Black	White	Asian	Black	White	Asian	Black	White
Before decongestion									
Mean	0.53	0.67	0.52	0.87	0.94	0.83	1.35	1.41	1.31
SD	0.10	0.10	0.12	0.22	0.23	0.24	0.35	0.42	0.42
Range	0.59-1.66	1.04-1.86	0.57-1.45	0.96-3.15	1.16-2.96	0.94-2.88	1.74-4.83	1.55-4.86	1.49-4.62
After decongestion									
Mean	0.61	0.81	0.64	1.47	1.64	1.51	1.99	2.20	2.08
SD	0.12	0.11	0.12	0.36	0.32	0.36	0.47	0.43	0.60
Range	0.65-1.99	1.27-2.03	0.91-1.73	1.65-5.61	2.19-4.58	1.95-4.51	2.49-6.17	3.12-6.49	2.39-6.28

Table 3. Mean volumes, standard deviations, and range (minimum-maximum)

	Asian	Black	White
Volume before decongestion			
Mean	7.92	8.94	8.25
SD	3.14	2.30	3.23
Range	10.12-40.43	11.97-31.18	10.92-51.90
Volume after decongestion			
Mean	11.67	13.06	11.90
SD	2.81	3.18	4.40
Range	16.31-42.01	17.52-43.09	15.02-64.62

ing. Alignment coordinates, including the angle of the acoustic tube, were carefully recorded to ensure reproducibility. The mean cross-sectional area (CSA) and volume measurements and their standard deviations at measured intervals into the nasal cavity were recorded by the AR computer software (Eccovision Software). Each test was done before and after the application of a short-acting topical decongestant (Neo-Synephrine). Decongestion eliminates the effects of the nasal cycle and provides valuable information about the soft tissue–mucosal factor with respect to bony-cartilaginous structures in the nose. Volumes between the nostril (0 cm) and a distance of 6 cm into the nose were calculated as were the CSAs at the first, second, and third valleys on the AR graph. Figure 1 shows a normal AR area-distance graph with corresponding valleys. The minimum CSA was designated CSA 1, the second valley CSA 2, and the third valley CSA 3.

Subjects were assigned to one of four racial groups on the basis of self-reference about their race: black, Asian, white, and Hispanic. CSA 1, CSA 2, CSA 3 (right and left sides combined), and volumes were compared by forming groups on the basis of race and sex. Data obtained before and after decongestion were evaluated separately.

Descriptive statistical analysis showed that the data obtained from CSA 1, CSA 2, and CSA 3 measurements have a normal distribution both before and after decongestion. The volume measurement data are a little skewed to the left.

RESULTS

Standard statistical analysis was done with use of a statistical analysis system language. The comparisons for CSA 1, CSA 2, CSA 3, and volumes before and after decongestion were done with a paired *t* test. The results showed that there is a significant difference between before and after decongestion ($p < 0.0001$). Also, statistically there is no interaction between decongestion and race, sex, height, and weight ($p > 0.05$). Therefore we analyzed the data before decongestion and after decongestion separately. Because of small sample size, the Hispanic group was excluded from statistical calculations.

Before Decongestion

A standard analysis of variance was done. It appears that there is no statistically significant difference between men and women within the same racial group for volume and CSA 1, CSA 2, and CSA 3 measurements. Therefore we combined measurements of men and women within the same race to obtain increased power in our statistical analysis. Height and weight do not have a significant effect on volume and CSA measurements. When compared among racial groups (men and women together), there is no statistically significant difference among racial groups for volume, CSA 2, and CSA 3, but there is a statistically significant difference for CSA 1.

The multiple linear regression models for different racial groups for the CSA 1 comparisons are formulated as follows:

Black: Yb = 1.059 + 0.077sex + 0.0027height + 0.0004weight + e

White: Yb = 0.7654 + 0.077sex + 0.0027height + 0.0004weight + e

Asian: Yb = 0.7729 + 0.077sex + 0.0027height + 0.0004weight + e

where Yb is CSA 1 before decongestion; for sex 1 is male and 0 is female; and e is random variation in this model for each person.

From the sample estimate, when sex, height, and weight are kept the same, the first valley area of white subjects is smaller than that of black subjects by 27.72% (of black subjects) ($p < 0.0001$) and that of Asian subjects is smaller than that of black subjects by 27.02% (of black subjects) ($p < 0.0001$). However, there is no statistically significant difference between Asian and white subjects ($p = 0.89$).

After Decongestion

The same analysis was done for the data after decongestion. The results are very similar to the results from before decongestion. The only statistically significant difference was between the CSA 1 measurements of

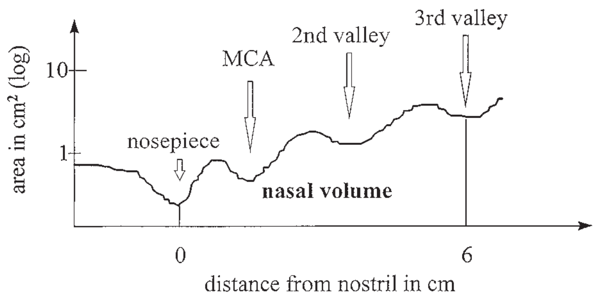

Fig. 1. Normal AR curve. Minimum CSA (*MCA*), second valley, and third valley correspond to CSA 1, CSA 2, and CSA 3, respectively.

black subjects and the CSA 1 measurements of Asian and white subjects. The multiple linear regression models for different racial groups for the CSA 1 comparison are as follows:

Black: Ya = 1.2369 + 0.1095sex + 0.003height + 0.0007weight + e

White: Ya = 0.8573 + 0.1095sex + 0.003height + 0.0007weight + e

Asian: Ya = 0.9202 + 0.1095sex + 0.003height + 0.0007weight + e

where Ya is CSA 1 after decongestion; for sex 1 is male and 0 is female; and e is random variation in this model for each person.

From the sample estimate, when sex, height, and weight are kept the same, the first valley area of white subjects is smaller than that of black subjects by 30.69% (of black subjects) ($p < 0.0001$) and that of Asian subjects is smaller than that of black subjects by 25.6% (of black subjects) ($p < 0.0001$). Again, there is no statistically significant difference between Asian and white subjects ($p = 0.27$).

Racial differences both before and after decongestion in CSAs regardless of sex are shown in Fig. 2. Black subjects had the largest CSA values at all valleys, followed by Asian and white subjects. The difference in the CSA at the first valley between black-race subjects and subjects of other races is significant both before and after decongestion.

Figure 3 shows the effects of decongestion on nasal volume measurements. In all race and sex groups, decongestion produced a significant increase in volume at 6 cm, which was detected by AR. The greatest increase in CSA with decongestion occurred at the second valley and the smallest increase in the CSA at the

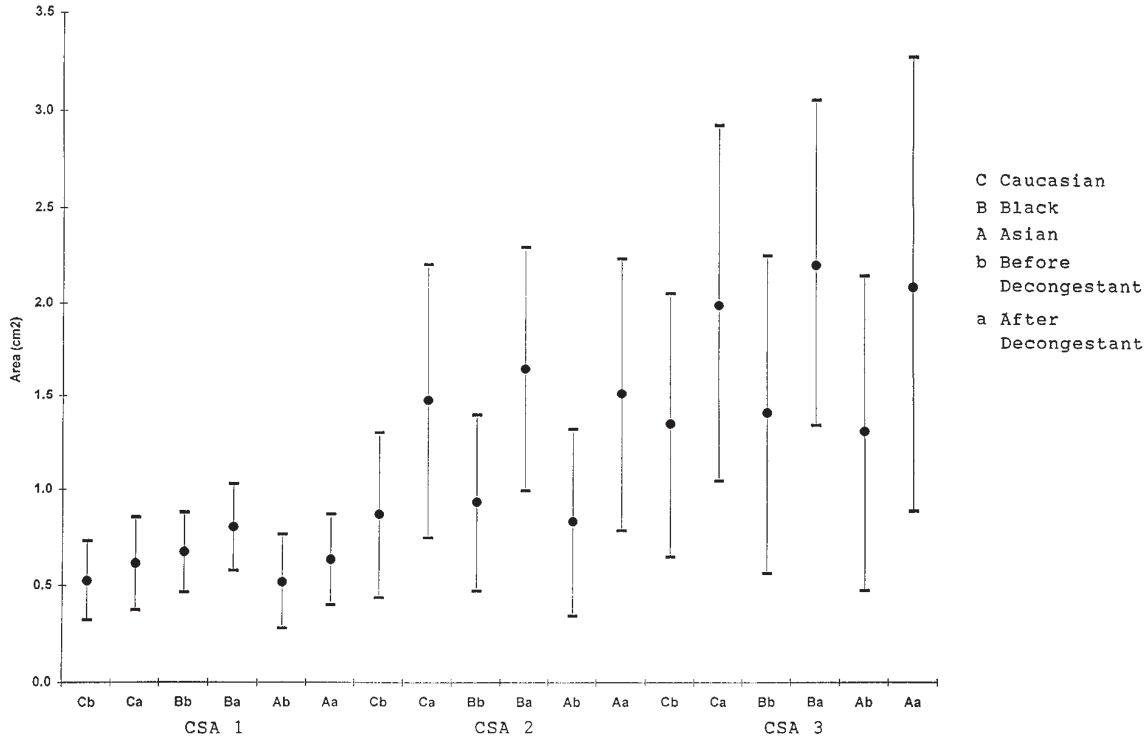

Fig. 2. CSA values before and after decongestion. Values are shown within 2 standard deviation ranges and mean.

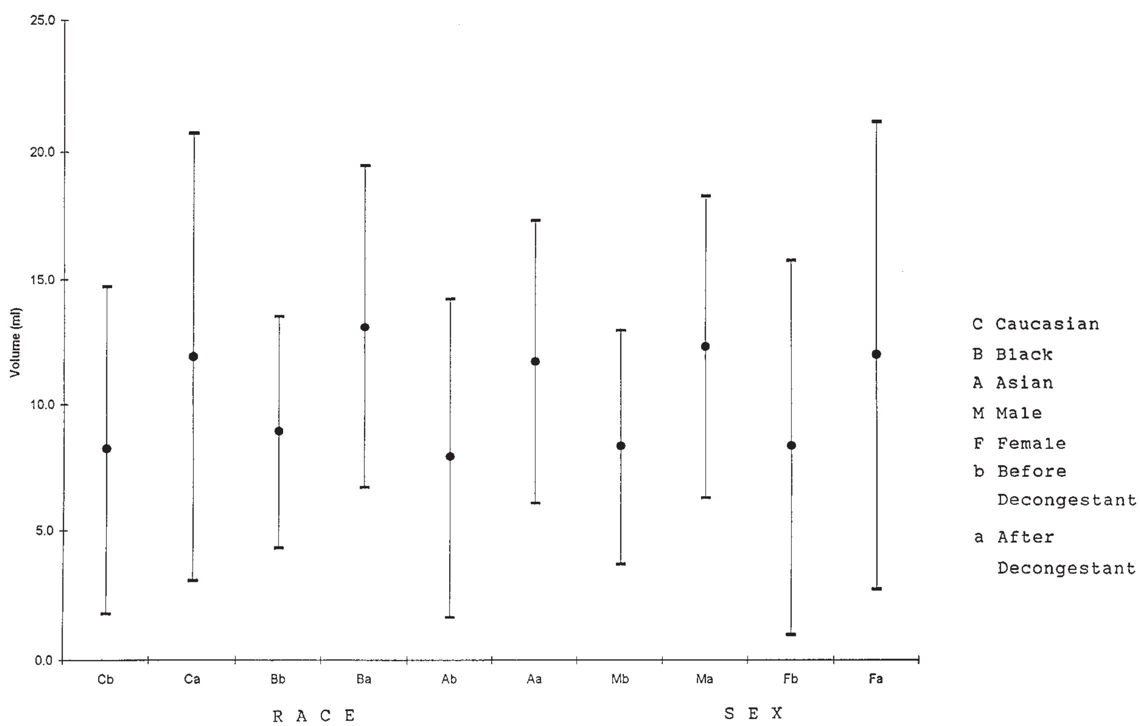

Fig. 3. Volumes before and after decongestion. Values are shown with regard to sex and race and within 2 standard deviation ranges.

first valley. The volumes before and after decongestion were not significantly different between groups on the basis of sex and race. Mean volumes and CSA values at each valley and their range (minimum and maximum observed values) with standard deviation are summarized in Tables 2 and 3.

DISCUSSION

The rather small number of subjects in the Hispanic male and female groups (4 and 3, respectively) makes statistical analysis difficult. On the other hand, the larger and relatively homogeneous groups (with respect to age, height, and weight) of Asian, white, and black men and women are suitable for analysis. The normative data presented should allow the researcher or clinician to compare "normal" values for AR done on research subjects or patients with changes produced by experimental conditions or clinical pathologic conditions, in a fashion similar to the normative data developed for normal hearing subjects used for interpreting audiograms. The importance of our data is that racial differences in nasal geometry can be demonstrated by AR. Because of these differences in nasal dimensions, "normal values" for nasal volumes and CSAs should be calculated according to race. The clinical implications of the normative values may serve to guide the physician in preoperative evaluation and during endoscopy and operations.

CONCLUSIONS

There are some differences in internal nasal geometry by race as detected by AR. A table of normal values in AR by race is presented. This database of normal values should provide a more accurate evaluation against which pathologic or experimental conditions may be judged.

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