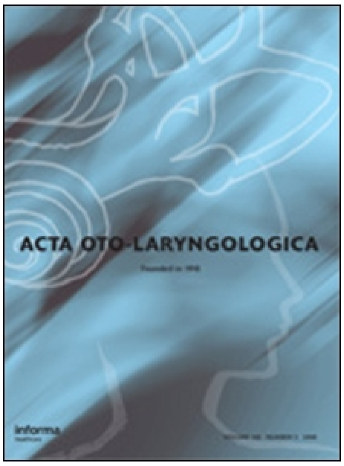

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Si Whan Kim [a]; Ji-Hun Mo [a]; Jeong-Whun Kim [a]; Dong-Young Kim [a]; Chae-Seo Rhee [a]; Chul Hee Lee [a]; Yang-Gi Min [a]
[a] Department of Otorhinolaryngology, Seoul National University College of Medicine, Seoul, Korea

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Change of nasal function with aging in Korean

SI WHAN KIM, JI-HUN MO, JEONG-WHUN KIM, DONG-YOUNG KIM, CHAE-SEO RHEE, CHUL HEE LEE & YANG-GI MIN

Department of Otorhinolaryngology, Seoul National University College of Medicine, Seoul, Korea

Abstract

Conclusion. The changes of nasal resistance and cross-sectional area (CSA) with aging could suggest that it might be attributed to the change (atrophy) of the non-erectile structural tissues including bone and soft tissues rather than the erectile tissues. Subjects older than 60 years of age had significantly slower ciliary beat frequency (CBF), which could suggest nasal function might begin to decrease at around 60 years of age. *Objectives.* Nasal physiology can be changed with aging, however, there has been little data that prove senile change of the nasal cavity. This study was conducted to evaluate the effect of aging on nasal resistance and ciliary movement of the nasal cavity. *Methods.* One hundred and fifty three healthy subjects were included in this study. Acoustic rhinometry and rhinomanometry before and after nasal decongestion, and CBF were measured. *Results.* The CSA at the attachment of the inferior turbinate was increased with age in both before and after decongestion. However, the difference of CSA between pre- and post-decongestion did not change significantly with age. At the nasal valve area, the CSA showed almost same values between age groups and the difference between pre-and post-decongestion was very small. The nasal resistance was markedly decreased from 2nd to 3rd decade and did not change significantly after 3rd decade. Subjects older than 60 years of age had significantly slower CBFs compared to those younger than 60 years (10.18 ± 0.98 *vs.* 12.43 ± 1.46) ($P < .001$).

Keywords: *Nasal cavity, aging, acoustic rhinometry, rhinomanometry, ciliary beat frequency*

Introduction

Aging is a basic physiologic phenomenon affecting structural and functional aspects of the body. Not only genetic traits but also environmental factors, trauma and disease can affect the process of aging. The nose also gets in the process of aging like other organs as the body changes. However, little attention has been paid to the nose, while lots of reports have been published on the aging process of other organs and tissues. There were some reports on aging process of the nose. Most of them were about nasal epithelial change, olfaction or taste and there has been only a few reports on change of nasal cavity and ciliary beat frequency with aging [1,2].

It is often observed that the nasal cavity in old age is dry and atrophic. It is possible to hypothesize that nasal cavity area would increase with the increasing age. However, there have been few reports on change of the nasal cavity area with reference to age. Edelstein reported that nasal resistance increased and nasal flow did not show any trend with age in his extensive study. However he did not evaluate the nasal cavity area [3].

In addition, it can be supposed that nasal ciliary beat frequency (CBF) may change with age. Mucociliary system, which is composed of cilia, mucus, and periciliary fluid, is an integral part of airway defense. Main function of mucociliary system is to eliminate inhaled particles. The overall propulsive effect depends on the arrangement of the cilia and CBF. If the nasal CBF is changing with age, it should be valuable data because CBF change may be one of reason for increase respiratory disease in old age. Thus, we would like to evaluate and analyze the effect of aging on the nasal cavity dimension and resistance with acoustic rhinometry and rhinomanometry and also on the change of CBF.

Corresponding: Chae-Seo Rhee, MD, Department of Otorhinolaryngology, Seoul National University Hospital, 28 Yongon-dong, Chongno-gu, Seoul 110-744, Korea. Tel: +82 2 2072 3991. Fax: +82 2 745 2387. E-mail: csrhee@snu.ac.kr

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The results showed that nasal resistance and cross sectional area (CSA) were steadily increased with age over 60. This finding could suggest that the atrophy of turbinate in old age might be attributed to the change of the non-erectile structural tissues including bone and soft tissues rather than the erectile tissues. Normal CBF was significantly decreased after 60 years old. These maybe suggest that nasal function could begin to decrease at age of over 60.

Materials and methods

Subjects

One hundred and fifty-three normal subjects were enrolled in this study from January 2003 to June 2006. There were 71 male and 82 female subjects. Age distribution of the subjects was summarized in Table I. Exclusion criteria included sinonasal symptoms, prior sinonasal surgery or deviated nasal septum, allergic rhinitis or other rhinitis, other sinonasal diseases or problems, upper respiratory infection, drug medication in previous 1 months or sleep related disorder. The study subjects were healthy volunteers from patients with non-rhinologic complaints or hospital employees. Informed consents were taken from all the subjects and institutional research review board of the hospital reviewed and approved the study.

Acoustic rhinometry and rhinomanometry was performed without nasal vasoconstriction after 20 minutes' acclimatization. Fifteen minutes after application of 1% phenylephrine into the nasal cavity, acoustic rhinometry and rhinomanometry was checked again. The room temperature and humidity were kept constant by means of central air conditioning and a humidifier. The ambient noise level was in accordance with manufacturers' requirements for acoustic rhinometry measurement. Nasal epithelial cells for measuring CBF were obtained from 78 subjects. Nasal brushes were taken a little posterior to the middle of inferior turbinate to eliminate the effect of exposure to irritants which may accelerate the CBFs.

Table I. Distribution of study subjects by sex and age.

Age (year)	Male	Female	Total
10–19	11	1	12
20–29	9	12	21
30–39	14	17	31
40–49	12	24	36
50–59	12	21	33
60–69	13	7	20
Total	71	82	153

Acoustic rhinometry

The Eccovision Acoustic Rhinometer® (Product code 11000, Hood Laboratories, MA, USA) was used for acoustic rhinometry. Subjects were seated upright in a straight backed chair facing straight ahead and were tested 3 times per each nostril using well fitted nose tip, which made an acoustically tight seal between the nostril and the nose tip. The mean CSA and their standard deviation were measured by the computer software (Eccovision software). The minimum CSAs at the first and second valley of the AR graph were designated as CSA1 and CSA2. The CSAs of the left and right side were added and analyzed with reference to age.

Rhinomanometry

Rhinomanometer 300® (ATMOS MedizinTechnik Gmbh & Co.KG, Germany), a kind of active anterior rhinomanometry, was used for pressure and flow measurement. Subjects were instructed to breathe through the adaptor that was connected to the manometer. Rhinomanometry was performed to both sides of the nose and flow and pressure measurements were performed at rest and 15 minutes after 1% phenylephrine application.

Pressure at 150 pascal was used for analysis and total resistance was calculated using following equation; Total Resistance $= 1/(1/R_{Right} + 1/R_{left})$. Total resistance and flow was analyzed with reference to age.

CBF measurement

The harvested epithelial cells were incubated in Dulbecco's Modified Eagle Medium-Ham's nutrient F12 (DMEM-F12; Gibco BRL, Grand Island, NY) at 37°C under 5% CO_2 in an incubator for 1 hour. A cluster of epithelial cells was placed in a specially designed sterile culture dish, which was maintained at 37°C throughout the experiment. Ciliary movement was observed using an immersion microscope at a magnification of $\times 600$. A digital charge-coupled camera (XC-HR50, Sony Co., Japan) capable of operating at 60 full frames per second speed transferred images to computer equipped with a frame grabber (PCVisonplus, Dalsa Co., St. Laurent, Canada). Ciliary movement was analyzed using software based on fast-Fourier transform [4].

Data analysis

SPSS 10.0 (SPSS Inc, Chicago, Illinois) was used for statistical analysis, and data were expressed as mean $\pm$SEM. Data with reference to age was analyzed with one-way ANOVA (analysis of variance) and Wilcoxon-signed rank test. In case of statistical significances, post hoc test (Duncan's method) was applied to identify difference between age groups. P value less than .05 was considered significant.

Results

Change of cross sectional area with age

While the CSA2 before decongestion increased statistically with age (one-way ANOVA test, $P = .19$), while the CSA1 showed almost same values. The nasal cavity area of CSA2 increased with decongestion in all age groups (Wilcoxon-signed rank test, $P < .05$). There were no statistical significances with aging in both before and after decongestion application. However, the differences in CSA2 before and after nasal decongestion did not change with aging (Figure 1). The difference of CSA1 before and after decongestion was very small. The CSA1 of 2nd decade was 0.93 ± 0.08 cm^2 and that of 7th decade was slightly increased to 1.01 ± 0.05 cm^2. The increment of CSA1 was most prominent from 2nd decade to 3rd decade while CSA2 is steadily increased with age. The result was almost same irrespective of sex.

Nasal resistance and nasal flow

Nasal resistances were significantly decreased after decongestion in each age group except 7th decade. Nasal resistance before decongestion of 2nd decade was significantly higher than that of 3rd decade, while other values were not significantly different among age groups (Figure 2). Both males and females showed same results and nasal decongestion did not affect the pattern of the results (Figure 3).

Nasal flow before decongestion showed increasing tendency from teens to sixties, though it was not significant (one-way ANOVA test, $P = .93$). Nasal flow increment was the most prominent from teens to 3rd decade as like drop of nasal resistances (Figure 3). Irrespective of nasal decongestion, nasal flow showed the same increasing tendency.

Ciliary beat frequency

The mean value of the CBFs of nasal cavity was 11.53 ± 1.40 Hz, Table II shows the summary of CBFs of the nasal cavity according to age, sex, and smoking, respectively. The CBFs in the subjects under the age of 60 years were faster than those of their older counterpart (12.43 ± 1.46 Hz *vs*. 10.18 ± 0.98 Hz). Figure 4 shows the CBFs of nasal cavity divided according to decade-intervals of age. The CBFs begin to decrease significantly over 60 year. However, no statistically significantly differences were observed in the CBFs of nasal cavity in terms of sex and smoking history.

Discussion

Acoustic rhinometry is well known to be a useful device measuring nasal dimension by detecting reflected acoustic waves. It has been used widely in

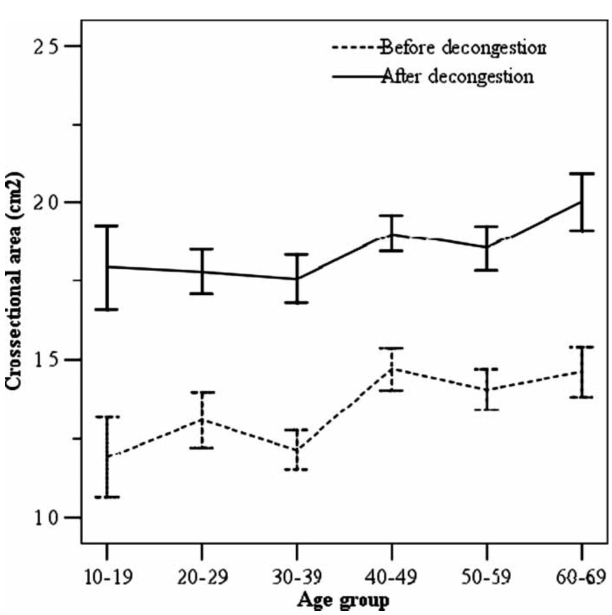

Figure 1. Cross sectional area (CSA2) measured by acoustic rhinomanometry as a function of age before (dotted line) and after (solid line) decongestion. There is a significant increasing tendency in CSA2 with age (one-way ANOVA test, $P = .019$).

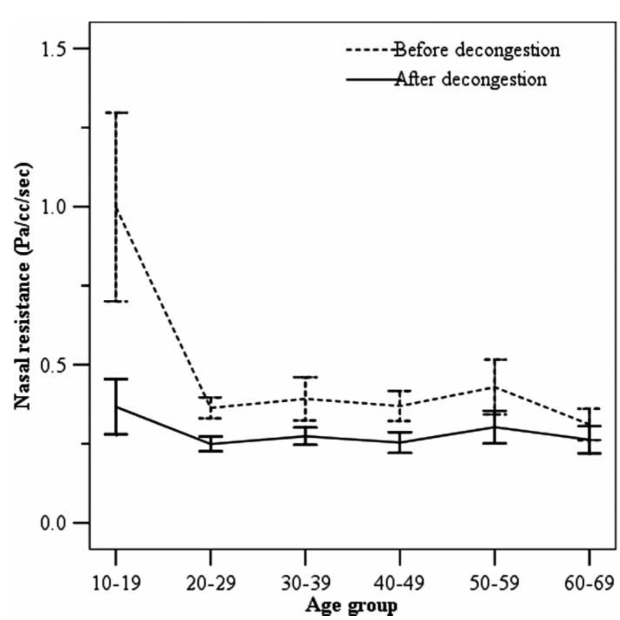

Figure 2. Nasal resistance measured by rhinomanometry as a function of age before (dotted line) and after (solid line) decongestion. There was a marked drop of nasal resistance after decongestion from 2nd to 3rd decade.

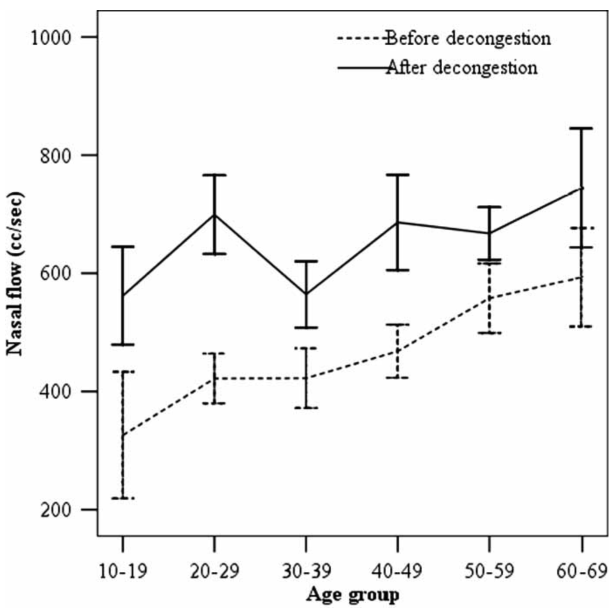

Figure 3. Nasal flow measured by rhinomanometry as a function of age before (dotted line) and after (solid line) decongestion. Nasal flow showed increasing tendency with age, which was not statistically significant.

clinical and experimental settings since it is non-invasive, fast, and easy to perform. Rhinomanometry is used to measure nasal resistance by measuring nasal flow and pressure difference between nasopharynx and atmosphere. These two methods are complimentary and provide accurate assessments of the nasal airway.

A lot of studies have been conducted using acoustic rhinometry and rhinomanometry; however, there have been a few studies on change of the nasal dimension and resistance with increasing age. Vic and Zajac studied nasal resistance and the nasal cavity area with 197 normal subjects [5]. They classified age groups into three; child (age 5 to 12 years), teen (age 13 to19 years) and adult (20 years or older). They found that nasal resistance decreased and nasal cavity area increased with age. Their results were consistent with our study, which shows the increment of nasal flow and decrement of

Table II. Ciliary beat frequency according to sex, aging and smoking.

		N	Ciliary beat frequency
Sex	Male	56	11.67 ± 1.41
	Female	24	11.12 ± 1.35
Age	<60	59	12.43 ± 1.46*
	>60	19	10.18 ± 0.98
Smoking	Smoker	32	11.56 ± 1.38
	Non-smoker	48	11.48 ± 1.50

Values are mean ± SD.
*Significantly different from their older counterpart ($P < .001$).

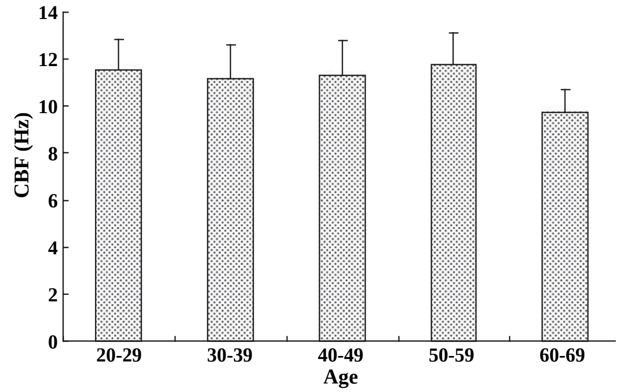

Figure 4. Ciliary beat frequency according to age. Ciliary beat frequency of the nasal epithelial cells was decreased at the age of over 60.

nasal resistance from teens to twenties. However, they divided age groups into only 3 groups that they could not give data in older age; even in the nasal cavity area was increased with aging.

Edelstein reported in his extensive study on aging of the normal nose that the nasal resistance increased with age and that there was no significant relationship between nasal flow and age [3]. The increase in nasal resistance was inconsistent with our data. We showed that nasal resistance decreased significantly from teens to twenties and there was no significant change in nasal resistance after twenties.

Warren and colleagues demonstrated that size of the airway influenced nasal resistance greatly when the smallest nasal cross-sectional area is under $0.4cm^2$, and to a lesser extent in larger airways [6]. Thus, we could deduce that nasal resistance would decrease with increasing age to some extent and that nasal resistance would not fall much beyond that extent. From teens to twenties, nasal dimension increased and nasal resistance decreased dramatically. If nasal dimension increased above some extent, nasal resistance would be stationary or would decrease rather than it would increase. Thus, that may be the reason why this study shows no increase of nasal resistance in older age.

CSA1 corresponds to the anatomic location of the nasal vestibule, and there is scanty erectile tissue in the nasal vestibule. The difference in CSA1 before and after nasal decongestion was minimal in our study, and it was consistent with that scanty distribution of erectile tissue in CSA1. CSA2 is termed as C-notch or minimal cross sectional area (MCA) 2, corresponding to the anterior half of the inferior turbinate or anterior end of middle turbinate [7]. CSA2 increased with increasing age and the difference before and after decongestion was much bigger than that of CSA1 in this study. An MRI study revealed that erectile tissues were distributed in the inferior turbinate, middle turbinate and nasal septum [8]. Since CSA2 represents the anterior half of the inferior turbinate and anterior end of middle turbinate as described previously, it matched with the distribution of the erectile tissues well and this study also showed that the erectile tissue was abundant around CSA2.

CSA2 increased with the increasing age; however, the difference of CSA2 before and after decongestion did not change significantly. In other words, the nasal cavity area increased; however, the mucosal shrinkage did not change with increasing age. There are several possibilities with the results. We could speculate several possibilities from these results. Atrophy of bone or other structural parts of the nasal cavity with the increasing age could be one of those, since the mucosal shrinkage did not change with age. Nasal bony growth could be the second possibility of the increasing nasal cavity area. Since the bony growth usually ends in twenties, the possibility of bony growth in old age may not be strong. To verify these possibilities, the ratio of dimension of the whole nasal cavity including bony structures to the dimension without bony structure could be evaluated with CT.

Nasal flow showed rather fluctuating result than other test values, and there were minimal differences between sexes. Nasal flow increased from teens to twenties, and nasal flow showed relatively stationary values after twenties. The fluctuating results of the nasal flow could be attributed to the fact that rhinomanometry was influenced by many factors, which included nasal cycle, nasal secretion, temperature, humidity, time of day, race and sex.

Some reports could not find an influence of age on CBF in respectively 23 and 60 biopsies from adults aged up to 60 years [9]. The other extensive study of CBF in 203 biopsies and after ciliogenesis in culture showed that up to the seventies nasal ciliary beat frequency is age independent [10]. Unfortunately, out study which showed decrease of CBF after sixties did not support previous studies. This discrepancy might be induced by different measurement techniques and racial and/or environmental factors. Our study revealed that CBF begun to decrease at the age of 60. Thus, we may speculate the nasal mucosal function including ciliary movement could begin to decrease around age of 60. However, we need additional studies to verify the effect of those decreased function on the clinical implications for nasal diseases or symptoms in old age.

In conclusion, nasal cavity area increased with the increasing age, irrespective of sex and/or nasal decongestion; however, the difference of CSA before and after nasal decongestion, which means shrinkage of the erectile tissues did not change. It could be deduced that those changes might be attributed to the change (atrophy) of the non-erectile structural tissues including bone and soft tissues rather than the erectile tissues. In addition we may also speculate the nasal mucosal function including CBF could begin to decrease around age of 60.

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