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Reference values for acoustic rhinometry in decongested school children and adults: the most sensitive measurement for change in nasal patency

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SUMMARY

Introduction: *Only a limited reference material for acoustic rhinometry (AR) exists for school children most often calculated as the minimum cross-sectional area (MCA) in the non-decongested nose. We want to establish a set of reference values for MCA and nasal volumes for both adults and children and include values also for the decongested nose and determine the most sensitive measurement for change in nasal patency.*

Method: *Data from two studies were used; one comprising of 53 (20M, 33F) school children, age 9-11 years, and one comprising 146 (127M, 19F) healthy workers in the wood industry. Measurements by acoustic rhinometry were done before and after decongestion with two puffs of oxymethazoline nasal spray (1mg/ml).*

Results: *We found the decongested nasal volume (2-5 cm) to be 3.71 cm^3 (3.58 - 3.84) in school children and 5.44 cm^3 (5.21-5.67) in adults. We found the volume from 2-5 cm into the nasal cavity to be the most sensitive measure of change in nasal patency by decongestion, and MCA to be the least sensitive in both adults and children.*

Discussion: *A larger study population of children, covering a broader range of age, is needed to stratify for gender and height. Our data in adults are in accordance with previous findings.*

Conclusion: *We have provided a reference material for acoustic rhinometry in school children and adults. Future evaluation of change in nasal patency should contain information about nasal volume from 2-5 cm into the nasal cavity and not just MCA in adults and school children.*

Key words: acoustic rhinometry, nasal patency, reference material, sensitivity

INTRODUCTION

Acoustic rhinometry (AR) is a non-invasive method that uses the reflection of sound waves to display cross-sectional area as a function of distance. The method was developed in 1977 [(1)] and has since been adapted to research in nasal airways [(2)]. Literature reports many studies on the evaluation of nasal patency in children, especially in infants and neonates but no reference material for children has been published. The most common parameter used to express nasal patency by AR has been the minimum cross-sectional area (MCA). A limited number of studies have focused on the distance to MCA in normally breathing and non-decongested school children [(3,4)]. Other studies have only reported data on minimum cross-sectional area [(5-7)]. In adults, data on nasal volume are more abundant [(6-12)].

Research of indoor climate and its impact on the nasal airways among children and adults is of growing interest. But the question still remains; what is the most sensitive parameter to describe change in nasal mucosa?

The purpose of this study is:

- To establish a reference material for acoustic rhinometric measurements for evaluation of the effect of decongestion in school children in order to create a reference for future studies.
- To find the most sensitive parameter of change in nasal mucosa in children and adults.

By answering the questions above, the interpretation and evaluation of studies based on acoustic rhinometry will be facilitated.

METHODS

Measurements in adults

Randomly selected workers from 50 furniture factories and 3

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control factories in Viborg County, Denmark, were measured by acoustic rhinometry as part of a study on nasal patency in workers exposed to wood dust. Measurements were successfully obtained in 146 males and 26 females, average age 37 years. Participants were chosen randomly and independent of their health status. For each person, height and weight was measured, and they answered a questionnaire focusing mainly on respiratory and allergic symptoms. Asthma was defined as ever self-reported asthma. Rhinitis was defined as at least two nasal symptoms in the form of sneezing, blockage and rhinorrhea at least two days/week. Self reported allergy was defined as season dependent asthma or season dependent hay fever or atopic dermatitis. Acoustic measurements were conducted bilaterally with 3 acceptable curves from each side prior to decongestion with two puffs of xylomethazoline nasal spray (1mg/ml) in both nostrils. Measurements were repeated after 10 minutes of decongestion. For detailed methodological description see Schlünssen et al [7].

Acoustic measurements in children

As part of a multinational EU pilot-project (HESE: Health in the School Environment), 53 children from two urban schools and two classes in each, in Aarhus, Denmark, were measured bilaterally by acoustic rhinometry. All children, age 9-11 years old (average 9.8 years), were invited to participate independent of their health status, but we required parental consent and answering of a health questionnaire focusing on symptoms of asthma, rhinitis and eczema. The criterion for rhinitis was self-reported nasal symptoms in terms of sneezing, blockage or rhinorrhea within the last 12 months combined with one of the following: eye symptoms or parental suspicion of specific hypersensitivity. The criterion for asthma was self-reported asthma or asthma symptoms within the last 12 months. Nine children were classified as having asthma and/or rhinitis. Twenty boys and 33 girls were included; one child was excluded due to lack of cooperation. Three acceptable measurements were obtained from each side of the nasal cavity. Immediately hereafter, nasal lavage with isotonic saline was done as part of the HESE project, followed by two puffs of xylometazoline spray (1 mg/ml) in both nostrils. Decongestion was allowed to work for 15 minutes before measurements were repeated.

Acoustic rhinometry

Basics of this method have previously been extensively described [2]. We used a pulse driven system (GJ Electronik, Skanderborg, Denmark), tube diameter 1.32 cm, sampling at 100 kHz. A standard nose model was used to control the calibration on the day of measurement in accordance with international specifications [8]. We have no data on the accuracy in the adult study but in the HESE study the mean volume deviation from the model was +0.6% in the distance interval corresponding to 2-5 cm in vivo. We used a conical nose adapter (University of Aarhus, Aarhus, Denmark) in adults and a standard child adapter from Hood Laboratories (Pembroke, MA, USA) in children.

Ethics

Both studies were approved by the county ethics committee.

Statistics

For both the adult and child groups we calculated a mean minimum cross-sectional area (MCA) and volume of both nasal cavities, (L + R)/2. Data were normally distributed in the child group. In adults, acoustic data before and after decongestion were log-normally distributed and are presented below as geometric means and their confidence intervals. The *change* of nasal patency after decongestion was normally distributed in both groups and tested by a paired t-test (H_0 = no change after decongestion). The t-values were used to determine the sensi-

Figure 1. Sensitivity parameters for change in nasal patency after decongestion. Statistical significance is expressed by a t-value. Volume measured from 2 to 5 cm from the entrance of the nasal cavity is substantially more sensitive than MCA. N=53 (children) and N=146 (adults).

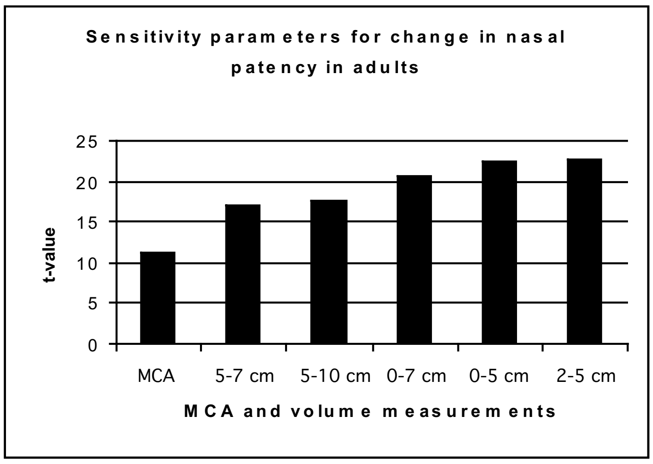


Figure 2. Sensitivity parameters for change in nasal patency after decongestion. Statistical significance is expressed by a t-value. Volume measured from 2 to 5 cm from the entrance of the nasal cavity is substantially more sensitive than MCA. N=53 (children) and N=146 (adults).

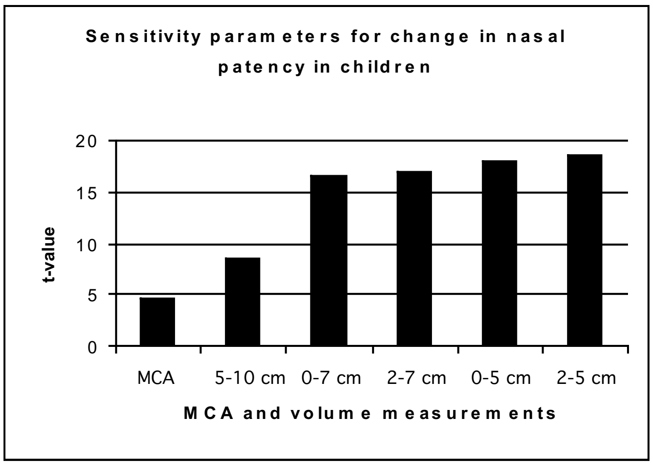


Table 1. School children: Acoustic parameters of change in nasal patency before and after decongestion (n=53). Mean values ± 95% CI. Volume is measured between distance-interval. MCA = Minimum cross-sectional area.

Parameters of nasal patency in school children	Before decongestion Mean ± 95% CI		After decongestion Mean ± 95% CI		Change in patency Mean ± 95% CI	
MCA (cm^2)	0.33	0.31 - 0.35	0.36	0.35 - 0.38	0.03	0.02 - 0.05
Vol 5-10 (cm^3)	10.38	9.73 - 11.03	12.89	12.20 - 13.57	2.51	1.92 - 3.10
Vol 0-7 (cm^3)	6.40	6.08 - 6.72	8.77	8.47 - 9.07	2.37	2.09 - 2.66
Vol 2-7 (cm^3)	5.37	5.06 - 5.68	7.73	7.44 - 8.02	2.36	2.08 - 2.64
Vol 0-5 (cm^3)	3.51	3.36 - 3.66	4.74	4.61 - 4.89	1.24	1.10 - 1.38
Vol 2-5 (cm^3)	2.48	2.34 - 2.62	3.71	3.58 - 3.84	1.22	1.09 - 1.36

Table 2. Adult woodworkers: Acoustic parameters of change in nasal patency before and after decongestion (n=146). Mean values ± 95% CI. Volume is measured between distance-interval. MCA = Minimum cross-sectional area. Gm = Geometric mean and CI.

Parameters of nasal patency in wood workers	Before decongestion Gm Mean ± 95% CI		After decongestion Gm Mean ± 95% CI		Change in patency Mean ± 95% CI	
MCA (cm^2)	0.61	0.58 - 0.64	0.73	0.70 - 0.77	0.13	0.11 - 0.15
Vol 5-10 (cm^3)	14.70	14.04 - 15.39	19.00	18.30 - 19.73	4.23	3.74 - 4.73
Vol 5-7 (cm^3)	4.49	4.28 - 4.70	5.92	5.68 - 6.17	1.44	1.26 - 1.62
Vol 0-7 (cm^3)	10.73	10.34 - 11.14	13.83	13.36 - 14.31	3.13	2.80 - 3.45
Vol 0-5 (cm^3)	6.22	6.01 - 6.43	7.87	7.62 - 8.14	1.68	1.52 - 1.85
Vol 2-5 (cm^3)	3.73	3.56 - 3.91	5.28	5.07 - 5.49	1.56	1.41 - 1.71

tivity of measurements. Association between parameters of nasal patency (MCA and volume) and smoking, height, gender, age and allergic symptoms was tested for by linear regression analysis.

RESULTS

For both groups, we did a regression analysis of smoking, height, gender, symptoms of rhinitis and/or asthma to MCA and volumes. In the child group no significant difference was found and children with self-reported asthma and rhinitis (n=9) were included in the following data analysis. In the adult group, only self reported allergy was correlated to values of nasal patency before decongestion, even after adjustment for height and gender. This correlation disappeared after decongestion. As one of the aims was to create a reference material, woodworkers with self-reported allergy (n=26) were excluded in the following analysis. There was neither effect of smoking, asthma, or rhinitis on baseline nor change of nasal patency, and they were included in the data analysis.

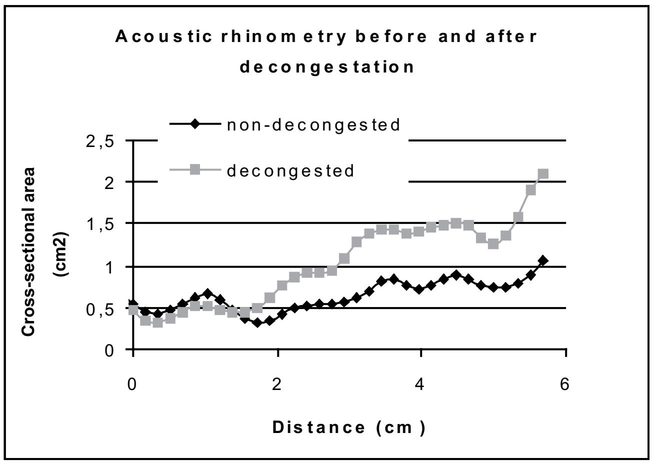
Unilateral MCA and nasal volume (mean ± 95% CI) before and after decongestion is presented in Table 1 for children. The nasal cavity measured from 2 to 5 cm had a volume of $2.5cm^3$ (2.3-2.6) before and $3.7cm^3$ (3.6-3.8) after decongestion. We found correspondingly MCA to be $0.33cm^2$ (0.31-0.35) before and $0.36cm^2$ (0.35-0.38) after decongestion. The corresponding values for adult woodworkers after exclusion of those with self-reported allergy are shown in Table 2.

For the comparison between the two mucosal states we included MCA and volumes obtained in varying distance-intervals of the nasal cavity: 2-5, 0-5, 0-7, 5-10 cm and additionally 2-7 cm in the child group and 5-7 cm in the adult group. The volume from 5-10 cm was included because a change in the ostia to the maxillary sinuses will cause changes in this volume [(9)].

For both groups all differences are highly significant, but the volume differences were more sensitive than the MCA (Figures 1 and 2). The anterior volume measured 2-5 cm from the nostril was the most sensitive parameter in both children and adults.

In addition we found the distance to the MCA to move *anteriorly* after decongestion by 0.57 cm (0.46-0.68) in adults and 0.25cm (0.11-0.33) in children (see example in Figure 3).

Figure 3. Acoustic measurements in one child before and after decongestion. After decongestion the MCA moves 0.77 cm anteriorly to be situated in a different anatomic part of the nasal cavity only due to slight changes in mucosal thickness.



DISCUSSION

AR has been used to map changes in nasal cavity geometry in adults, children and infants, but there does not seem to be a sufficient reference material for school children. Furthermore, earlier measurements have mostly been in non-decongested children.

Our measurements in children were limited to mostly caucasians living in an urban environment. However, the children are probably representative for the age group 9-11 years. We have also decided to include data from all children since there was no significant effect of health status, height and gender on MCA or volume (Table 1).

Data suggest that there is a dose-dependent change in nasal patency during the day in relation to exposure to wood-dust [15], but no correlation between nasal patency before work and the subsequent wood dust concentration was found. It therefore seems reasonably to include subjects irrespective of the wood dust exposure. We did find a correlation between self-reported symptoms of allergy and baseline values of nasal volume in the non-decongested. We therefore excluded those with self-reported allergy to obtain a reference material in adults.

Existing data, mainly from non-decongested children, report an MCA in accordance with our findings supporting an external validity [3,4]. In adults one-sided decongested volumes of 5.59cm^3 (0-4cm) [8], 11.9cm^3 (0-6cm) [10], 15.02cm^3 (0-8cm) [11] have been reported. These findings are in good agreement with our data (Table 2).

A study on infants (1-16 months) reports a one-sided non-decongested volume of 2.37cm^3 (0-4cm) [10]. As data on adults or infants are clearly not applicable to school children there is still need for a reference material.

The popularity of MCA is undoubtedly due to that it can be easily visualized. However, our data suggest that volume parameters measured in the anterior part of the nose are the most sensitive for change in nasal patency due to change in mucosal swell. This is not surprising as the maximum effect of decongestion is found 4 cm from the nostrils [11].

Figure 3 presents an example of acoustic measurements before and after decongestion in a child. It illustrates the reason why the MCA often moves after decongestion and why the MCA should not be perceived as a fixed anatomical landmark. Instead the location of MCA depends on the state of nasal congestion, which again is an argument against using the volume to different minima to indicate changes in mucosal swelling, because such volume changes may be very much dependent on the motion of the minima.

We have used the same type of equipment for acoustic measurements in both children and adults and can expect the same type and degree of error to have occurred in both studies.

CONCLUSION

We found that the mean cavity volume of school children measured from 2 to 5cm had a magnitude of 2.5cm^3 (2.3-2.6) (mean ± 95% CI) before and 3.7cm^3 (3.6-3.8) after decongestion, representing the closest yet to a reference material for children aged 9-11 years. A larger study population is needed for stratification of gender and height. Data on adult woodworkers are in accordance with previous studies and also constitutes a reference material. We found that measurement of anterior nasal cavity volumes rather than MCA is the most sensitive measure for change in mucosal swell during decongestion. We recommend using the volume measured from 2 to 5cm from the nostril instead of the MCA though only marginally better than other volume intervals. This is applicable for both adults and children.

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