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# MEASURING NASAL VOLUMES WITH ACOUSTIC RHINOMETRY

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A b s t r a c t: *Objectives*. Acoustic rhinometry is used to objectively measure the minimal cross sectional area and volumes of nasal cavities. However, no data for healthy subjects has been reported in Macedonia. Therefore, we wanted to establish the normal range among healthy adults and to evaluate the changes after nasal decongestion.

*Methods:* We included 50 males and 50 females in this study (mean age: 23.2 years; age range: 19 to 40 years). An acoustic rhinometer was used to evaluate the first minimal cross-sectional area (MCA1), the distance from the tip of the probe to the first minimal cross-sectional area (D1), the second minimal cross sectional area (MCA2), the distance from the tip of the probe to the second minimal cross sectional area (D2), the volume between the tip of the nosepiece and 3 cm into the nasal cavity (V03), the volume of the nasal cavity between 2 to 5 cm from the tip of the nosepiece (V25), the volume of the nasal cavity between 4 to 7 cm from the tip of the nosepiece (V47), and the volume between the tip of the nosepiece and 7 cm into the nasal cavity (V07). These measurements were taken before and after nasal decongestion.

*Results:* Data acquired from the male group before decongestion were as follows: MCA1 L: 0.71 ± 0.07 ($cm^2$); D1 L: 0.34 ± 0.05 (cm); MCA2 L: 0.46 ± 0.13 ($cm^2$); D2 L: 2.46 ± 0.11 (cm); MCA1 R: 0.73 ± 0.06 ($cm^2$); D1 R: 0.35 ± 0.05 (cm); MCA2 R: 0.47 ± 0.11 ($cm^2$); D2 R: 2.41 ± 0.18 (cm); V03 L 2.59 ± 0.82 ($cm^3$); V25 L; 4.83 ± 1.93 ($cm^3$); V47 L; 7.82 ± 2.94 ($cm^3$); V07 L: 11.48 ± 4.23 ($cm^3$); V03 R 2.55 ± 0.72 ($cm^3$); V25 R; 4.71 ± 1.76 ($cm^3$); V47 R; 7.60 ± 2.30 ($cm^3$); V07 R: 12.03 ± 3.65 ($cm^3$); data acquired from the female group before decongestion were: MCA1 L: 0.65 ± 0.12 ($cm^2$); D1 L: 0.35 ± 0.05 (cm); MCA2 L: 0.50 ± 0.12 ($cm^2$); D2 L: 2.36 ± 0.15 (cm); MCA1 R: 0.65 ± 0.11 ($cm^2$); D1 R: 0.35 ± 0.04 (cm); MCA2 R: 0.49 ± 0.13 ($cm^2$); D2 R: 2.41 ± 0.13 (cm); V03 L 2.64 ± 0.58 ($cm^3$); V25 L; 5.11 ± 1.17 ($cm^3$); V47 L; 8.30 ± 2.20 ($cm^3$); V07 L: 12.38 ± 3.19 ($cm^3$); V03 R 2.42 ± 0.56 ($cm^3$); V25 R; 4.43 ± 1.34 ($cm^3$);

V47 R; 7.35 ± 2.29 ($cm^3$); V07 R: 11.06 ± 3.19 ($cm^3$) The increase in MCA1 and MCA2 after nasal decongestion was significant ($p < 0.001$), both in females and males. The increases in V03, V25, V47 and V07 after nasal decongestion were statistically significant both in the female and male groups as well ($p < 0.001$).

*Conclusion:* Acoustic rhinometry is a convenient method for assessing the geometry of the nasal cavity. The maximal effect of decongestion is found in the anterior and middle parts of the nasal cavity, at the level of the inferior and middle turbinates.

**Key words:** acoustic rhinometry, minimal cross sectional area, nasal decongestant, nasal volume.

## *Introduction*

Nasal breathing without difficulty is a complex matter and is influenced by several factors. There are various objective tests for nasal airway assessment to help physicians in understanding the nasal airway function. Acoustic rhinometry (AR) was first described by Hilberg in 1989 [1]. It is one of the most commonly used tests for objective measurements of the nasal airway [2]. AR evaluates the geometry of the nasal cavity with acoustic reflections and provides information about the nasal cross-sectional area and nasal volume within a given distance into the nasal cavity. AR presents a shock wave to the nasal airway and then by measuring the reflected sound a profile of the cross-sectional areas through each side of the nose may be obtained. Changes in the cross-sectional area of the nose cause changes in acoustic impedance that affect the reflection of the sound [1]. This test defines the site of obstruction in the nasal airway. This is a helpful means of diagnosis of nasal obstructing diseases such as rhinitis, snoring, and tumours. It is also useful for comparing preoperative and postoperative results in nasal surgery [1–4]. It is a painless, noninvasive procedure that requires little cooperation from patients and has been applied to both children and adults [5, 6].

However, there is no evidence in the literature that the acoustic rhinometer has been used to measure nasal volumes after nasal decongestion. Therefore, we defined the normal ranges for nasal cross-sectional areas and volumes in 100 normal adults with an acoustic rhinometer, both before and after the application of 0.05% oxymetasoline.

## *Material and methods*

This study included 100 healthy adults (50 males and 50 females; age range: 19 to 40 years; mean age: 23.2 years) selected from our out-patients.

Exclusion criteria were as follows: 1) obvious nasal deformity or septal deviation, 2) history of prior trauma, nasal operation, allergic rhinitis, nasal polyposis or chronic rhinosinusitis, 3) current use of medication that could influence the congestive state of the nasal mucosa, and 4) recent upper respiratory infections within two weeks prior to the selection process, 5) negative nasal swab for bacteria and negative pneumoslide done at the Microbiology and Parasitology Institute. The impulse acoustic rhinometer (GMI Ltd, UK) used in this study has been described fully in previous reports. The room temperature was kept between 20 and 25 C, and the relative humidity was around 50% to 55%. All subjects remained seated for at least 20 minutes to acclimatize to the hospital environment before testing [7]. The nose piece was positioned parallel to the sagittal plane of the head and at 45° to the coronal plane, and was applied to produce an acoustic seal without distorting the outer nose. The tested subjects were asked to hold their breath and avoid swallowing while we acquired the acoustic data. Changes in cross-sectional area cause a portion of the energy to be reflected back toward the wave tube and these reflections are sensed by the microphone. The cross-sectional area was computed from the intensity of the echo. The data were converted to an area-distance function and plotted on a semilogarithmic scale of area ($cm^2$) on the y-axis and distance (cm) on the x-axis. Both nasal cavities of all subjects were examined before and 15 minutes after 2 sprays of 0.05% oxymetasoline solution were applied to each nostril [8, 9]. Three consecutive readings were used to calculate an average value for each data point. An entire average acoustic rhinometry curve was generated for each nasal cavity before and after decongestion. Acoustic data included: 1) the first minimal cross-sectional area (MCA1), 2) the distance from the tip of the probe to the first minimal cross-sectional area (D1), 3) the second minimal cross-sectional area (MCA2), 4) the distance from the tip of the probe to the second minimal cross-sectional area (D2), 5) the volume between the tip of the nosepiece and 3 cm into the nasal cavity (V03), 6) the volume of the nasal cavity between 2 and 5 cm from the tip of the nosepiece (V25), 7) the volume of the nasal cavity between 4 cm and 7 cm from the tip of the nosepiece (V47), and 8) the volume between the tip of the nosepiece and 7 cm into the nasal cavity (V07). Statistical calculations were analysed by the Mann-Whitney U test.

## *Results*

The ranges, averages, and standard deviation of MCA1, D1, MCA2, D2, V03, V25, V47 and V07 before and after the application of nasal decongestant are listed in tables 1, 2, 3 and 4.

Table 1 – Табела 1

*MCA1, D1, MCA2, D2 of left and right nostril before nasal decongestion in men and women*
*MCA1, D1, MCA2, D2 од левата и десната носна шуплина пред деконгестија кај мажи и жени*

| | Before nasal decongestion Men | ± St. Dev Before nasal decongestion Men | Before nasal decongestion Women | ± St. Dev Before nasal decongestion Women | N Men | N Women |
|---|---|---|---|---|---|---|
| MCA1 L | 0.718800 | 0.079442 | 0.659600 | 0.122695 | 50 | 50 |
| D1 L | 0.348000 | 0.055528 | 0.358800 | 0.050193 | 50 | 50 |
| MCA2 L | 0.465600 | 0.131056 | 0.502000 | 0.123592 | 50 | 50 |
| D2 L | 2.464000 | 0.111355 | 2.364000 | 0.157797 | 50 | 50 |
| MCA1 R | 0.730000 | 0.061981 | 0.651200 | 0.117485 | 50 | 50 |
| D1 R | 0.354000 | 0.053697 | 0.358000 | 0.043589 | 50 | 50 |
| MCA2 R | 0.473600 | 0.111051 | 0.490400 | 0.135354 | 50 | 50 |
| D2 R | 2.416000 | 0.184120 | 2.416000 | 0.131276 | 50 | 50 |

Table 2 – Табела 2

*MCA1, D1, MCA2, D2 of left and right nostril after nasal decongestion in men and women*
*MCA1, D1, MCA2, D2 од левата и десната носна шуплина по деконгестија кај мажи и жени*

| | After nasal Decongestion Men | ± St. Dev After nasal decongestion Men | After nasal Decongestion Women | ± St. Dev After nasal decongestion Women | N Men | N Women |
|---|---|---|---|---|---|---|
| MCA1 L | 0.775833 | 0.085563 | 0.708077 | 0.120632 | 50 | 50 |
| D1 L | 0.367083 | 0.067790 | 0.362692 | 0.054004 | 50 | 50 |
| MCA2 L | 0.580417 | 0.120415 | 0.640769 | 0.100117 | 50 | 50 |
| D2 L | 2.466667 | 0.081650 | 2.415385 | 0.140548 | 50 | 50 |
| MCA1 R | 0.784583 | 0.077850 | 0.733077 | 0.110987 | 50 | 50 |
| D1 R | 0.365833 | 0.071561 | 0.370769 | 0.050193 | 50 | 50 |
| MCA2 R | 0.615417 | 0.125420 | 0.645385 | 0.150844 | 50 | 50 |
| D2 R | 2.458333 | 0.155806 | 2.446154 | 0.150282 | 50 | 50 |

The increase in MCA1 L ($p = 0.005074$), MCA2 L ($p = 0.000005$), MCA1 R ($p = 0.000068$) and MCA2 R ($p = 0.000001$) were significant after nasal decongestion, both in males and females. MCA1 = the first minimal cross-sectional area; MCA2 = the second minimal cross-sectional area; D1 = the distance from the tip of probe to the first minimal cross-sectional area; D2 = the distance from the tip of probe to the second minimal cross-sectional area.

Table 3 – Табела 3

*Volumes of both nasal cavities before nasal decongestion*
*Волумени од двеше носни шуплини пред деконгесшија*

| | Before nasal Decongestion Men | ± St. Dev Before nasal decongestion Men | Before nasal Decongestion Women | ± St. Dev Before nasal decongestion Women | N Men | N Women |
|---|---|---|---|---|---|---|
| V03R | 2.55760 | 0.720140 | 2.42240 | 0.565356 | 50 | 50 |
| V25R | 4.71800 | 1.765965 | 4.43240 | 1.342409 | 50 | 50 |
| V47R | 7.60600 | 2.305226 | 7.35120 | 2.297490 | 50 | 50 |
| V07R | 12.03800 | 3.657683 | 11.06800 | 3.252873 | 50 | 50 |
| V03L | 2.59520 | 0.825440 | 2.64400 | 0.585121 | 50 | 50 |
| V25L | 4.83120 | 1.935225 | 5.11040 | 1.173224 | 50 | 50 |
| V47L | 7.82560 | 2.940425 | 8.30280 | 2.202696 | 50 | 50 |
| V07L | 11.48120 | 4.237703 | 12.38200 | 3.197842 | 50 | 50 |

Table 4 – Табела 4

*Volumes of both nasal cavities after nasal decongestion*
*Волумени од двеше носни шуплини по деконгесшија*

| | After nasal Decongestion Men | ± St. Dev After nasal decongestion Men | After nasal Decongestion Women | ± St. Dev After nasal decongestion Women | N Men | N Women |
|---|---|---|---|---|---|---|
| V03R | 3.16042 | 0.743280 | 2.97154 | 0.688457 | 50 | 50 |
| V25R | 6.28208 | 2.303608 | 6.09577 | 2.010795 | 50 | 50 |
| V47R | 10.09625 | 3.113192 | 9.63462 | 2.671997 | 50 | 50 |
| V07R | 15.44708 | 4.319249 | 14.27846 | 4.014975 | 50 | 50 |
| V03L | 3.22125 | 0.823847 | 3.23346 | 0.583362 | 50 | 50 |
| V25L | 6.54083 | 2.392143 | 7.02654 | 1.671713 | 50 | 50 |
| V47L | 9.92500 | 3.678174 | 10.95115 | 2.673270 | 50 | 50 |
| V07L | 14.36250 | 5.077143 | 15.75923 | 4.147227 | 50 | 50 |

The increase in right and left volumes of nasal cavities V03, V25, V47 and V07 after nasal decongestion were statistically significant both in male and female groups ($p < 0.001$). V03 = the volume between the tip of the nosepiece and 3 cm into the nasal cavity; V25 = the volume of the nasal cavity between 2 cm to 5 cm from the tip of the nosepiece; V47 = the volume of the nasal cavity between 4 cm to 7 cm from the tip of the nosepiece; V07 = the volume between the tip of the nosepiece and 7 cm into the nasal cavity.

## *Discussion*

Acoustic rhinometry is relatively noninvasive, simple, and requires less patient cooperation than other methods. This method can be applied to children as young as 3 years old. Acoustic rhinomerty is used as a tool for diagnosis and follow-up of treatment in both rhinology and rhinosurgery. It has been used in septoplasty and turbinate surgery, in rhinoplasty, in paranasal sinus problems and in sleep apnoea patients. Similarly, this is a reliable method of showing changes in the nasal cavities before and after a given treatment, for example in allergic rhinitis patients, or in the diagnosis of allergies in nasal provocation tests. The technique is appropriate for evaluating patients with no nasal airflow (laryngectomy patient) and those with total or near-total nasal obstruction. These groups cannot be studied with rhinomanometry or peak flow. However, in cases with severe nasal obstruction, the acoustic rhinometry analysis of the depths of the nose is unreliable. Also, deviation of nasal septum and hypertrophy of inferior nasal turbinates may influence the results of acoustic rhinometry as well. Our results cover a wide range of nasal cavity volumes and equate with the normal range in the healthy population. They suggest that volumes vary widely between subjects. We found a good correlation between values of left and right nostrils with no overall marked lateral asymmetry. In this study, a significant increase in MCA1 and MCA2 after nasal decongestion was noted both in the male and female groups ($p = 0.001$). We also found an increase in V03, V25, V47, and V07 after nasal decongestion, both in the male and the female groups. The cavernous erectile tissue in the nasal submucosa is most developed over the inferior and middle turbinates and the septal cavernous body [10]. Thus the greatest effect of decongestion after receiving 0.05% oxymetasoline occurred in the anterior and middle part of the nasal cavity. Data obtained in this study also showed a significant increase in the cross-sectional area among MCA2 (anterior portion of inferior nasal turbinates) and a prominent increase in volumes of the anterior portion (V03) and the middle portion of the nasal cavity (V25). However, significant differences before and after decongestion were noted on the posterior portion of the nasal cavity (V47). These might have been due to the following factors: 1) interference from the contralateral nasal cavity in the posterior portion of the tested side; 2) underestimation of deeper areas and volumes due to narrowing of the nose which produces a cross-sectional area of 0.6–0.7 cm2 [11–15]; 3) distortion of the acoustic pulse after shrinkage of mucosa of the middle and the inferior turbinate; 4) the accuracy of acoustic rhinometry which diminishes with distance from the nostril [16, 17]; 5) leak of acoustic pulse into the paranasal sinuses after the orifices are extended following decongestion [18].

## *Conclusion*

Acoustic rhinometry is a convenient method of assessing the geometry of the nasal cavity. This report studied the minimal cross-sectional area and volumes of nasal cavities in normal healthy adults. The maximal effect of decongestion was found in the anterior and middle part of the nasal cavity, at the level of the inferior and middle turbinates.

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Р е з и м е

## МЕРЕЊЕ НА НАЗАЛНИТЕ ВОЛУМЕНИ СО АКУСТИЧНА РИНОМЕТРИЈА

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*Вовед:* Акустичната ринометрија (АР) се користи за објективно мерење на минималните напречни пресеци и волумени на назалните кавитети. Иако методата се користи подолго време, ние немаме податоци за вредности од АР кај здрави субјекти. Затоа, сакавме да етаблираме нормални вредности кај здрави индивидуи, и да ги евалуираме промените по назална деконгестија.

*Методи:* Ние вклучивме 50 мажи и 50 жени во студијата, на возраст од 19 до 40 години, со просечна старост од 23,2 години. Се користеше акустичен ринометар за да се одреди првата ареа со минимален напречен пресек (MCA1), должината од врвот на сондата до првата ареа со минимален напречен пресек (D1), втората ареа со минимален напречен пресек (MCA2), должината од врвот на сондата до втората ареа со минимален напречен пресек (D2), волуменот помеѓу врвот на носната сонда и 3 см во внатрешноста на носната шуплина (V03), волуменот на носната шуплина помеѓу 2 и 5 см од врвот на носната сонда (V25), волуменот на носната шуплина помеѓу 4 и 7 см од врвот на носната сонда (V47), и волуменот помеѓу врвот на носната сондата и 7 см во внатрешноста на носната шуплина (V07). Мерењата беа правени и пред и по назалната деконгестија.

*Резултати:* Вредности кои беа добиени кај мажите пред назалната деконгестија се следните: MCA1 L: 0,71 ± 0,07 ($cm^2$); D1 L: 0,34 ± 0,05 (cm); MCA2 L: 0,46 ± 0,13 ($cm^2$); D2 L: 2,46 ± 0,11 (cm); MCA1 R: 0,73 ± 0,06 ($cm^2$); D1 R: 0,35 ± 0,05 (cm); MCA2 R: 0,47 ± 0,11 ($cm^2$); D2 R: 2,41 ± 0,18 (cm); V03 L 2,59 ± 0,82 ($cm^3$); V25 L; 4,83 ± 1,93 ($cm^3$); V47 L; 7,82 ± 2,94 ($cm^3$); V07 L: 11,48 ± 4,23 ($cm^3$); V03 R 2,55 ± 0,72 ($cm^3$); V25 R; 4,71 ± 1,76 ($cm^3$); V47 R; 7,60 ± 2,30 ($cm^3$); V07 R: 12,03 ± 3,65 ($cm^3$); вредности добиени за жените пред назалната деконгестија се: MCA1 L: 0,65 ± 0,12 ($cm^2$); D1 L: 0,35 ± 0,05 (cm); MCA2 L: 0,50 ± 0,12 ($cm^2$); D2 L: 2,36 ± 0,15 (cm); MCA1 R: 0,65 ± 0,11 ($cm^2$); D1 R: 0,35 ± 0,04 (cm); MCA2 R: 0,49 ± 0,13 ($cm^2$); D2 R: 2,41 ± 0,13 (cm); V03 L 2,64 ± 0,58 ($cm^3$); V25 L; 5,11 ± 1,17 ($cm^3$); V47 L; 8,30 ± 2,20 ($cm^3$); V07 L: 12,38 ± 3,19 ($cm^3$); V03 R 2,42 ± 0,56 ($cm^3$); V25 R; 4,43 ± 1,34 ($cm^3$); V47 R; 7,35 ± 2,29 ($cm^3$); V07 R: 11,06 ± 3,19 ($cm^3$).

Добивме сигнификантно зголемување на вредностите за MCA1 и MCA2 ($p < 0,001$) по назалната деконгестија и кај мажите и кај жените. Исто така, добивме статистички сигнификантно зголемување на волумените V03, V24, V47 и V07 по назалната деконгестија и кај двете групи ($p < 0,001$).

*Заклучок:* Акустичната ринометрија е метод за проценка на геометријата на назалните кавитети. Максималниот ефект на назалната деконгестија е на предниот и средниот дел од назалните кавитети во ниво на долната и средната носна школка.

**Клучни зборови:** акустична ринометрија, ареа со минимален напречен пресек, назална деконгестија, назален волумен.

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