RELATIVE METRIC INDICATORS OF THE UPPER AND LOWER PARTS OF THE INTERNAL NASAL VALVE LUMEN AND THEIR IMPACT ON NASAL RESPIRATORY AND OLFATORY FUNCTIONS

Volodymyr O. Shkorbotun¹, Maksym O. Ovsienko¹,², Yaroslav V. Shkorbotun¹,³

¹ – Shupyk National Healthcare University of Ukraine, Kyiv, Ukraine
² – Municipal Non-Profit Enterprise «Kyiv City Clinical Hospital No.9», Kyiv, Ukraine
³ – State Institution of Science «Research and Practical Center of Preventive and Clinical Medicine» State Administrative Department, Kyiv, Ukraine

Summary

The aim of the article: To study the influence of absolute and relative metric indicators of the lumen of certain parts of the internal nasal valve on the effectiveness of olfactory and respiratory functions of the nasal cavity.

Materials and methods: A comparison of the metric values of the internal nasal valve, air resistance and odor perception in 32 patients after septoplasty was performed, depending on the quality of life and complaints according to SNOT 22. Group 1 consisted of 22 patients who complained of subjective feelings of nasal insufficiency (SNOT 22-9-20 scores). Control group consisted of 10 patients who were satisfied with septoplasty results (SNOT 22-0-7 scores). Rhinomanometry was performed according to the PARM method, olfactometry was carried out using the Sniffin’ Sticks psychophysical tests, and planimetry on CT was performed in the RadiAnt DICOM Viewer 2022.1 program, using the closed polygon tool.

Results: Significant differences in the relative values of the ratio of the upper part of the valve area to the lower part were observed between the two groups of patients. A significant difference in better odor perception was noted in group 2. It was 0.7±0.02 in patients of the control group, and 0.4±0.02 in patients of Group 1. Air resistance in the nasal cavity during unilateral rhinomanometry did not significantly differ (0.28±0.04 and 0.26±0.07 Pa/cm³/sec). The average score during olfactometry in patients of the control group was 11.4±0.13, in patients of Group 1 it was 8.8±0.2, which indicates the presence of hyposmia (p>0.05).

Conclusions: The ratio of the areas of the upper and lower parts of the internal nasal valve does not affect the overall airway resistance in the nose, but it can disrupt the distribution of air between the nasal passages. When evaluating the results of septoplasty, in particular, if the patient is not satisfied with nasal breathing, it is important to pay attention to the ventilation of the upper parts of the nasal cavity. One of the markers of its impairment may be hyposmia.

Keywords: upper respiratory tract, pathology of the nose and paranasal sinuses, nasal passages, internal nasal valve, septoplasty, nasal breathing, sense of smell, quality of life

INTRODUCTION

Modern surgical correction of nasal septum deviation is primarily aimed at increasing the airflow through the nasal passages by expanding the lumen of the nasal cavity in its main part, where the nasal turbinates are located [4].

However, it has been proven that the optimal outcome of septoplasty depends not only on the patency of the corrected nasal cavity and the overall volume of air passage, but also on the features of air distribution within all nasal passages [12]. It is under these conditions that all the functions of the nose can be implemented, including odor reception, which is a significant component of subjective satisfaction with nasal breathing and, consequently, the quality of life [5].

In some cases, this is not related to the absence of the lumen in the upper or middle nasal passage, but rather to
the disruption of air distribution by the internal nasal valve due to its deformation and relative narrowing or expansion at various levels. This is explained by the fact that air moves from the diffuser of the external nasal valve to the nasal passages predominantly through the part of the internal nasal valve where it meets the least resistance.

According to Xiong G-X et al. (2008), under normal conditions, the airflow distribution through the nasal passages is as follows: approximately 50% of the total volume passes through the lower nasal passage, up to 35% through the middle nasal passage, and up to 15% through the upper nasal passage [1]. According to other researchers, the distribution of airflow through the nasal passages differs slightly. They suggest that approximately 35-37% of the airflow passes through the lower nasal passage, about 50% through the middle nasal passage, and correspondingly 12-15% through the upper nasal passage [1, 14]. At the same time, it is observed that the airflow through the lower nasal passage proceeds in a straight and predominantly laminar manner, whereas through the middle and upper nasal passages, it follows a parabolic trajectory with turbulence [1].

In light of the above, a detailed study of the absolute and relative metric indicators of the lumen of certain parts of the nasal cavity, as well as their influence on the efficiency of the olfactory and respiratory functions of the nasal cavity, is an important and promising research direction.

THE AIM OF THE ARTICLE

To study the influence of absolute and relative metric indicators of the lumen of the internal nasal valve on the olfactory and respiratory functions of the nose.

MATERIALS AND METHODS

The study was carried out at the Department of Otorhinolaryngology of the Municipal Non-Profit Enterprise «Kyiv City Clinical Hospital No.9» and State Institution of Science «Research and Practical Center of Preventive and Clinical Medicine» State Administrative Department, which are clinical sites of the Department of Otorhinolaryngology of Shupyk National Healthcare University of Ukraine. The study involved 22 patients (Group 1) who had undergone septoplasty due to nasal septum deviation and complained of subjective nasal breathing insufficiency with SNOT-22 scores ranging from 8 to 20, which corresponds to mild impairment of quality of life. The control group (Group 2) consisted of 10 patients who were completely satisfied with septoplasty results, with SNOT-22 scores less than 8. The examinations were conducted in the remote follow-up period, which is 6 months or more after the intervention. The Ukrainian version of the SNOT-22 questionnaire [10] was used for the survey.

An additional inclusion criterion for patients in the control group, in addition to satisfaction with nasal breathing, was the mandatory requirement for them to have undergone a head CT examination after septoplasty. These CT examinations were assigned by other specialists to eliminate head pathology.

Exclusion criteria included blockage of the upper and middle nasal passages as indicated in CT scan, acute and chronic rhinosinusitis, acute respiratory infections of the upper respiratory tract, allergic and vasomotor rhinitis, and established essential olfactory disorders.

The distribution of patients into groups according to the SNOT-22 score and their characteristics by age and gender are presented in table 1.

<table>
<thead>
<tr>
<th>Patient age (years)</th>
<th>Gender</th>
<th>Patient groups</th>
<th>M ± m</th>
<th>Women n (%)</th>
<th>Men n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n-22)</td>
<td></td>
<td></td>
<td>30.2±1.5</td>
<td>13 (59.1 %)</td>
<td>9 (40.9 %)</td>
</tr>
<tr>
<td>2 (n-10)</td>
<td></td>
<td></td>
<td>35.6±3</td>
<td>5 (50 %)</td>
<td>5 (50 %)</td>
</tr>
</tbody>
</table>

As can be seen from table 1, no significant differences in age and gender were found between the groups. The groups are representative for the study.

Complaints and medical history were collected from all patients. A standard ENT examination, including anterior rhinoscopy, endoscopic examination of the nasal cavity, and cone beam computed tomography of the paranasal sinuses or head CT were performed. CT planimetry was performed with the RadiAnt DICOM Viewer 2022.1 program using the closed polygon tool. Total air resistance during nasal breathing and separately for each half of the nose was determined by the anterior active rhinomanometry (AAR) method using the OPTIMUS rhinomanometer (Ukraine, state registration No.14777/2015).

Airway resistance during unilateral testing at pressure of 150 Pa, less than 0.3 Pa/cm3/second, was considered normal [11]. Olfactory acuity was assessed using the Sniffin’ Sticks psychophysical tests (Burghardt®, Wedel, Germany) – 12-11 scores for normosmia, 10-7 scores for hyposmia, and less than 7 scores indicating anosmia [2].

To standardize the investigation conditions, the patients acclimated to room temperature (20-22 °C) for 30 minutes before examination. Local decongestants were used to eliminate the influence of the mucosal component on nasal breathing.
When examining separate halves of the nose, the opposite half was excluded using Merocel nasal packing.

The evaluation of CT scan results was performed using multiplanar image reconstruction to determine the presence of the lumen between the nasal septum and turbinates and the planimetry of the lumen of the internal nasal valve in an oblique frontal projection in its cross-section at the level of the narrowest part, corresponding to a line drawn through the front edge of the lower turbinate from the bottom of the nasal cavity to the level of attachment of the lateral cartilage to the nasal bone [7]. Taking into account the projection of the valve relative to the nasal passages, its lumen was divided into upper and lower parts. The horizontal dividing line was determined by the transition level from the upper acute-angled form of the valve lumen to the rounded form, corresponding to the level of attachment of the lower turbinate and accordingly, the upper edge of the lower nasal passage (figure 1).

Since the assessment of the research results was carried out separately for each half of the nose, the total number of examinations that were subject to analysis and statistical processing was 64 cases (group 1 – 44, group 2 – 20).

The statistical analysis of the obtained data was carried out by non-parametric statistical methods with the use of the Mann-Whitney test. The arithmetic mean (M) and the standard deviation (m) were used to describe data with a normal distribution. Statistical processing of the data was carried out using the STATISTICA v.6.1 software product.

RESULTS

The results of the study on patients’ nasal airflow resistance and olfactory acuity, examined separately for each half of the nose, are presented in table 2.

<table>
<thead>
<tr>
<th>Patient groups (n-number of examinations)</th>
<th>Airflow resistance during AAR R_150 (Pa/cm³/sec)</th>
<th>Olfactometry results using Sniffin’ Sticks in scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n = 44)</td>
<td>0.28±0.04</td>
<td>8.8±0.2</td>
</tr>
<tr>
<td>2 (n = 20)</td>
<td>0.26±0.07</td>
<td>11.4±0.13</td>
</tr>
<tr>
<td>P_1-2</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

As can be seen from table 2, patients from the control group (Group 2) who were satisfied with the quality of nasal breathing, had an average air resistance during AAR of 0.26±0.07 Pa/cm³/sec, which is within the normal range. In patients of Group 1, who had subjective complaints about the quality of nasal breathing, this indicator was slightly
higher – 0.28±0.02 Pa/cm³/sec, although there was no statistically significant difference between them (p>0.05). At the same time, the olfactometry data indicate a significant impairment of olfactory acuity in patients of Group 1. While patients of the control group had an average olfactometry score of 11.4±0.13, in patients of Group 1, it was 8.8±0.2, indicating hyposmia (p>0.05).

Metric data for determining the total area of the lumen of the internal nasal valve, separately for each half of the nose, are presented in table 3.

### Table 3

<table>
<thead>
<tr>
<th>Patient groups (n-number of examinations)</th>
<th>Areas of measuring the internal nasal valve lumen (mm²)</th>
<th>Ratio of the area of the upper part of the internal nasal valve to the area of its lower part</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total area</td>
<td>Upper part</td>
</tr>
<tr>
<td>1 (n = 44)</td>
<td>112.2±3.1</td>
<td>36.2±1.53</td>
</tr>
<tr>
<td>2 (n = 20)</td>
<td>116.3±1.7</td>
<td>49.3±1.02</td>
</tr>
<tr>
<td>P&lt;1.2</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

The data presented in table 3 show the absence of significant differences in the indicator of the total area of the internal nasal valve in patients of both groups. However, it is important to note the difference in the relative values, specifically the ratio of the areas of the upper part of the valve to the lower part. While in patients of the control group (Group 2), the ratio of the area of the upper part to the lower part is 0.7±0.02, in the patients of Group 1, it is 0.4±0.02. This difference is statistically significant (p<0.05), as well as the difference in the separate areas of the upper and lower parts of the internal nasal valve between the groups. It is noteworthy that the upper part of the internal nasal valve has a smaller area in patients of Group 1, who reported subjective complaints of nasal breathing disturbances and, consequently, a lower quality of life.

**DISCUSSION**

The personal subjective perception of nasal breathing in patients after septoplasty can be influenced by various factors. Among them are the features of nasal cavity aeration after surgery, blood supply and innervation, the psycho-emotional state of a patient, the conditions of their everyday life, and, of course, the error of the technique of surgical intervention [3, 4, 5]. All these factors can affect the condition of the mucous membrane that directly interacts with the inhaled air, and, accordingly, play an important role in the formation of the personal feeling of nasal breathing on a psycho-emotional level.

The visual assessment of the relationship between patient complaints and postoperative anatomy of the nasal cavity can be quite challenging. To analyze and discuss the data obtained in the study, the main research indicators are presented in the summary table 5.

As can be seen from table 5, the average air resistance value in the nasal passages and the rhinometry results in patients of both groups were within the normal range [6]. That is why, all patients noted an improvement in the respiratory function of the nose after the intervention, but upon deeper questioning, some of them complained of insufficient quality and lack of feeling of fullness in nasal breathing, which was reflected in the quality of life indicator according to SNOT-22. When comparing the results of AAR and the average value of the total cross-sectional area of the internal nasal valve, it should be noted that these indicators did not differ significantly in both groups. However, a significant difference in the areas of the upper and lower parts of the internal nasal valve is noteworthy (p<0.05). At the same time, the area of the upper part of the nasal valve in patients of Group 1 was smaller compared to that of patients of Group 2, and the area of the lower part, on the contrary, was larger in patients of Group 1 compared to this indicator in the control group.

**Table 5**

| Indicators of nasal breathing and olfactory acuity in patients with a different ratio of the areas of the upper and lower parts of the internal nasal valve |
|-------------------------------------------------|---------------------------------|-----------------|-----------------|
| Studied indicators                               | Patient groups                  | Reliability of the difference P<1.2 |
| Resistance at AAR (R<sub>150</sub> Pa/cm³/sec)  | I n = 44 (M±m)                  | 0.28±0.04       | 0.26±0.07       | >0.05 |
| Sniffin’ Sticks olfactory acuity (scores)        | II n = 20 (M±m)                 | 8.8±0.22        | 11.4±0.13       | <0.05 |
| Total area of the internal nasal valve lumen (mm²) |                                 | 112.2±3.1       | 116.3±1.7       | >0.05 |
| Area of the upper part of the internal nasal valve (mm²) |                                 | 36.2±1.53       | 49.3±1.02       | <0.05 |
| Area of the lower part of the internal nasal valve (mm²) |                                 | 76.03±2.4       | 66.8±1.6        | <0.05 |
| Ratio of the area of the upper part of the internal nasal valve to its lower part | | 0.4±0.02 | 0.7±0.02 | <0.05 |
Accordingly, the ratio of the areas of the upper and lower parts of the internal nasal valve differ significantly. In patients of Group 1, this indicator was 0.4±0.02, while in the control group, this value was 0.7±0.02. It is important to note that the value of 0.7±0.02 (control group) is closer to the data published in the study (Zhao [14], Borojeni [1]) regarding the distribution of air between the nasal passages. According to this study, under normal conditions, approximately 35-37% of airflow passes through the lower nasal passage.

It is evident that the absolute dimensions of the nasal cavity and the ratio of the areas of its upper and lower part represent an important anatomical characteristic that affects the airflow patterns in the nasal cavity. This characteristic determines how air is distributed between the upper and lower flows and plays a key role in determining the transition from laminar to turbulent airflow. Thus, changes in the configuration of the internal nasal valve can lead to restricted aeration of the upper nasal passage and, consequently, lead to conductive hyposmia.

The results of the study of olfactory acuity in patient groups indicate significant differences in the obtained indicators. In Group 1, the average olfactory acuity score was 11.4±0.13, indicating normal olfactory function. Meanwhile, in patients of Group 2, an average score was 8.8±0.2, signifying reduced olfactory sensitivity and categorized as hyposmia.

The analysis of the obtained data leads to the conclusion on the crucial role of olfactory perception in the formation of the subjective feeling of nasal breathing quality [8]. The effectiveness of this sensation, among other factors, also depends on the shape and lumen of the nasal valve, which regulates the direction of the airflow through the nasal passages [9]. Therefore, during corrective interventions in the nasal cavity, the surgeon should pay attention not only to the size of the lumen in the upper part of the internal nasal valve, but also to the ratio of its area to the area of the lumen in the lower part. If the lower part of the valve, located in the lower nasal passage, is too wide, the airflow, due to the path of least resistance, will predominantly pass through it, robbing the upper nasal passage, where olfactory receptors are located. This leads to compromised aeration and hyposmia in the corresponding half of the nose.

Understanding the physics of airflow in the nasal cavity can help the surgeon consciously and predictably influence the correction of this area during septoplasty. Additionally, an olfactory test before the intervention can be a marker for conductive olfactory dysfunction, in particular, insufficient ventilation of the olfactory area in the upper nasal passage.

It is crucial to emphasize the importance of unilateral studies in these patients, since the possibility of compensating the general air resistance and the olfactory acuity with the opposite half of the nose to normal levels may prevent patients from suspecting potential deviations of individual indicators in certain halves of the nose.

Thus, one of the reasons for patient dissatisfaction with the results of corrective interventions on the nasal septum and structures (septoplasty) may be insufficient expansion of the lumen of the upper parts of the internal nasal valve or the creation of an excessive lumen in its lower part – resection of the front parts of the quadrangular cartilage of the nasal septum without reimplantation or excessive resection of the lower concha part, especially its front end.

**CONCLUSIONS**

1. Air distribution between the nasal passages occurs in the area of the internal nasal valve, depending on its shape and the size ratio at different measurement levels.

2. The ratio of the areas of the upper and lower parts of the internal nasal valve does not affect the overall resistance to the passage of air through the nose, but may disrupt the airflow distribution between the nasal passages.

3. When evaluating septoplasty results, especially if a patient is not satisfied with nasal breathing, it is worth paying attention to the ventilation of the upper parts of the nasal cavity. Hyposmia can serve as one of the markers for its disruption.

4. If there are complaints of insufficient nasal breathing after septoplasty, the total air resistance during nasal breathing may be within the normal range. However, the cause of the complaints may be related to conductive hyposmia due to the disruption of airflow redistribution at the level of the internal nasal passage.

**The prospects for further research.** The study of the airflow dynamics in the nasal cavity depending on the shape of the internal nasal valve would be beneficial to complement with the Computational fluid dynamics simulation method, which could improve the predictability of functional rhinosurgical interventions outcomes.

**FUNDING AND CONFLICT OF INTEREST**

The article is self-funded. The authors declare no conflict of interest.

**COMPLIANCE WITH ETHICAL REQUIREMENTS**

The study was conducted in compliance with the bioethical principles of the Helsinki Declaration «Ethical principles for medical research involving human subjects». 
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Відносні метричні показники верхнього та нижнього відділів просвіту внутрішнього носового клапана та їх вплив на дихальну та нюхову функції носа

Володимир О. Шкорботун1, Максим О. Овсієнко1,2, Ярослав В. Шкорботун1,3

1 – Національний медичний університет України імені П. Л. Шупика, м. Київ, Україна
2 – Комунальне некомерційне підприємство «Київська міська клінічна лікарня № 9», м. Київ, Україна
3 – Державна наукова установа «Науково-практичний центр профілактичної та клінічної медицини» Державного управління справами, м. Київ, Україна

Мета: Вивчити вплив абсолютних та відносних метричних показників просвіту окремих частин внутрішнього носового клапана на ефективність нюхової і дихальної функцій носової порожнини.


Результати: Отримані достовірні відмінності відносного показника співвідношення площ верхнього та нижнього відділів внутрішнього носового клапана двома групами обстежених пацієнтів. У пацієнтів контрольної групи він становив 0,7±0,02, а у пацієнтів першої групи – 0,4±0,02. Опір повітря в носовій порожнині при унілатеральному риноманометричному дослідженні не мав достовірної різниці (0,28±0,04 і 0,26±0,07 Па/см3/сек). Середній бал при ольфактометрії у пацієнтів контрольної групи дорівнював 11,4±0,13, у пацієнтів першої групи – 8,8±0,2, що вказує на наявність у них гіпосмії (р>0,05).

Висновки: Показник співвідношення площ верхнього та нижнього відділів ВНК не впливає на загальний опір проходження повітря через ніс, але може порушувати розподіл повітря між носовими ходами. При оцінці результатів септопластики, зокрема коли пацієнт не задоволений якістю носового дихання, варто звернути увагу на вентиляцію верхніх відділів носової порожнини, одним із маркерів її порушення може бути гіпосмія.

Ключові слова: верхні дихальні шляхи, патологія носу та приносових синусів, носові ходи, внутрішній носовий клапан, септопластика, носове дихання, нюх, якість життя