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CASE REPORT

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# Computational Aerodynamics in Nasal Septal Perforation

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## Abstract

Nasal septal perforation (NSP) remains a problem, and treatment of it is still controversial. NSP leads not only to disturbances in the NC aerodynamics, but also to disturbances in warming and moistening of the inhaled air. By using the computational fluid dynamics (CFD) method, we evaluate disturbances in warming and moistening of the inhaled air in cases of NSP. We emphasize that an adverse effect of NSP begins with a disorder of air heating and moisturizing, and believe that a NSP must and can be closed as early as it is possible. (**International Journal of Biomedicine. 2019;10(1):82-85.**)

**Key Words:** nasal septum • nasal septal perforation • computational fluid dynamics • surgical reconstruction

## Abbreviations

**CFD***,* computational fluid dynamics; **NS**, nasal septum; **NSP**, nasal septal perforation; **NC**, nasal cavity

## Introduction

Nasal septal perforation (NSP) is an anatomical defect of the cartilaginous and/or bone NS and it remains a severe problem to many patients. It is well recognized that NSP has a negative impact on the NC aerodynamics, leading to whistling during inspiration, crusting, recurrent nasal bleeding, nasal obstruction and other symptoms.[1-3] CFD simulation is a modern method to evaluate the influence of nasal passage geometry on the NC aerodynamics.[4-6] Today, by using CFD simulation, we can not only quantify the flow variables, such as velocity, pressure, and streamline, but also simulate the warming and moisturizing function of the inhaled air.[7] According to the general practice, only symptomatic perforations require surgical treatment to relieve symptoms; however, nobody takes into account heating and moisturizing disorders of the inhaled air.[8,9]

The aim of this study was to evaluate how NSP affects the NC physiology *in vivo* and consider the significance of early surgical closure of the NS defect.

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## Case Report

A 24-year-old white male was referred to the department of otorhinolaryngology with complaints of nasal bleeding, crusting and noisy nasal breathing. These symptoms appeared at the age of 18, and NSP was diagnosed. Medical treatment had been performed for 6 years, but therapy proved to be ineffective. Endoscopic examination of the patient's NC revealed NSP with a width of 15 mm and height of 10.5 mm in the anterior part of NS, crusting and signs of blood. CT examination revealed NSP; paranasal sinuses were intact (Figures 1 and 2).

Surgical reconstruction of the NSP was performed. The quadrangular cartilage was removed, turned in a front-to-back direction and returned to its former place. The mucosa from inferior turbinates was fitted to the place of the removed NS mucosa. Two years after the surgery, a CT examination was performed, which revealed that the anatomy of the NC was normal (Figures 3 and 4).

With the purpose of studying the NSP aerodynamics, we used high-resolution CT images, which were taken before and after surgical closure. Based on CT data, appropriate geometric models were generated, using a combination of several commercially available, pre-processing software programs. Our patient had an NSP of elliptical shape (width of 15 mm and height of 10.5 mm). The cross-sectional area of the NSP was 12.2 $cm^2$. The perforation started at a distance of 9mm from the nostril and ended at 24mm from the nostril.

Meshing is an important part of CFD simulation. The grid independency test was performed, and an unstructured three-dimensional mesh was generated, consisting of 2,500,000 cells (we used the program tool Ansys Meshing).

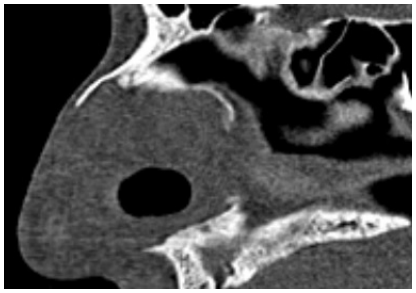

***Fig. 1.*** *Sagittal CT scan. Septal perforation of the cartilaginous part of NS.*

***Fig. 2.*** *Coronal CT scan. Septal perforation of the cartilaginous part of the NS.*

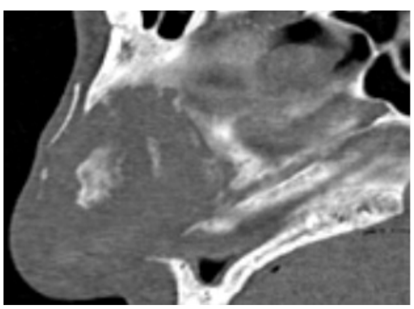

***Fig. 3.*** *Sagittal CT scan. Two years after the surgery: the normal anatomy of the NS.*

***Fig. 4.*** *Coronal CT scan. Two years after the surgery: the normal anatomy of the NS.*

<u>Boundary conditions</u>

CFD simulation is based on an approximate solving of the Navier-Stokes equations on unstructured meshes. The inhaled air was assumed to be a turbulent flow in boundary conditions of a large pressure drop (a range of pressure drops from 0 Pa in the inlet of the nostril to 50 Pa in the nasopharynx) and a flow rate of 300ml/s. That required using the so-called Reynolds averaged Navier-Stokes equation to account for the turbulence effects. A no-slip velocity boundary condition was assumed on the airway walls and the gravitational effects on the airflow were neglected. Numerical fluid simulation with heat and humidity transport was performed according to the method of Kumahata.[10] The temperature of the inhaled air was 25°C and the relative humidity was 35%.

The NS is an important part of the nasal cavity. In cases of NSP, the NS function is not executed, causing airflow exchange between two nostril sides of the NC through the NSP. According to the study performed by Cannon et al., the larger size of the NSP in the anterior location of the NS causes a larger cross-flow volume through the NSP.[3]

The detrimental effect of airflow leakage through the NSP is based not only on airflow exchange through the NSP, but also on an increase of total velocity of the inhaled air. In our study, total airflow velocity in a case of NSP was 17m/s (normal value is <12 m/s) (Figure 5). After the NSP reconstruction, total airflow velocity decreased and reached normal values (Figure 6).

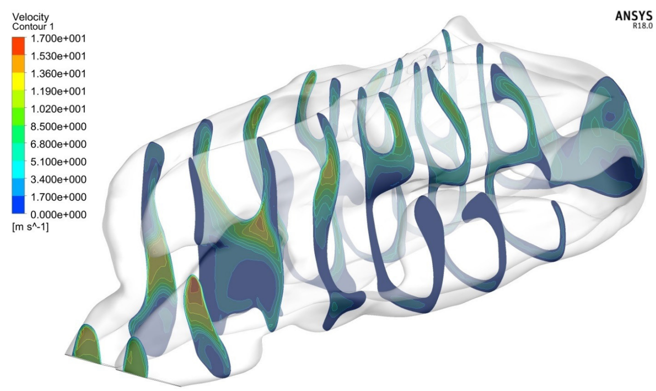


***Fig. 5.*** *Sagittal CT scan of the nasal cavity. Airflow velocity streamlines and cross-sectional air exchange through the NSP.*

The NC anatomy is created so that anterior parts of the inferior turbinates keep the inhaled air, giving time to contact the inhaled air with mucosa for heating and moisturizing. In the case of NSP, this process is disturbed as the total airflow velocity increases in the cartilaginous part of the NS. We found that the temperature and relative humidity of the airflow in the nasopharynx was lower than normal. The first diapason of temperature was from 32°C to 34°C and relative humidity was from 93% to 96%; the second diapason of temperature was from 35°C to 37°C and relative humidity 100% (Figure 7).

As seen from Figure 8, the coolest area in the NC was located in the NSP area. Thus, inhaled air was heated not only because of high total air velocity, but also because of large air leakage through the perforation. After the NSP reconstruction, the process of heating and moisturizing of the inhaled air was recovered (Figure 8).

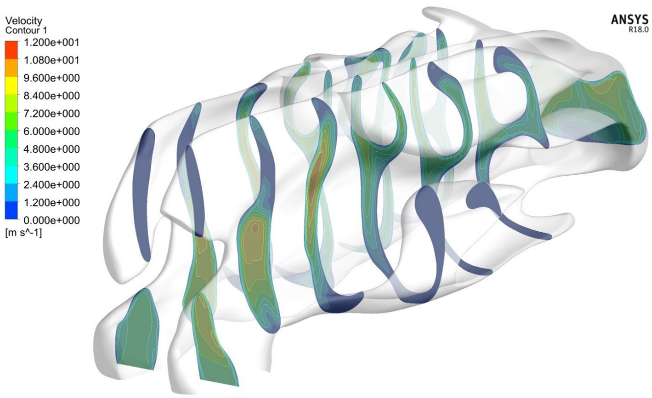


***Fig. 6.*** *Sagittal view of the nasal cavity after the NSP reconstruction. Airflow streamline passes through each side of the nasal cavity. Total airflow velocity decreased and reached normal values*

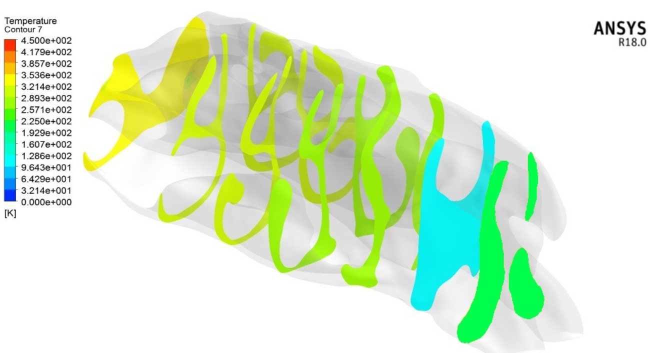


***Fig. 7.*** *Sagittal view of the nasal cavity. The temperature and relative humidity of the airflow in the nasopharynx is lower than normal. The coolest area in the nasal cavity is corresponded to the area of the NSP.*

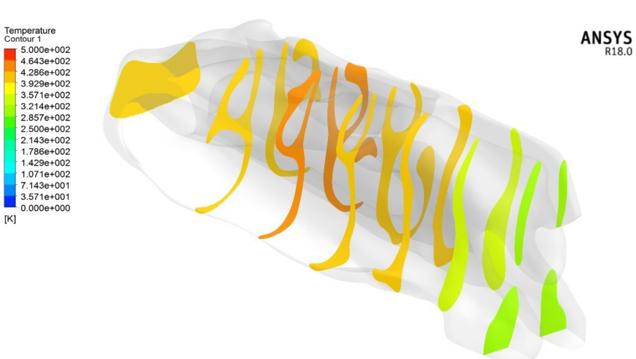


***Fig. 8.*** *Sagittal view of the nasal cavity after the NSP reconstruction. The process of heating and moisturizing of the inhaled air is normal.*

## Discussion

Nasal septal perforation remains a problem, and treatment of it is still controversial. As is common, only clinically significant nasal septal perforations are recommended to surgery, while small-sized nasal septal perforations are ignored. This happens because only obvious symptoms of nasal septal perforation such as whistling during breathing, frequent nasal bleeding, and crusting, are taken into account as a reason for surgery, but disturbances of the temperature and humidity in the nasal cavity are ignored. Our study shows that decreased temperature of the inhaled air in the nasopharynx provides an adverse effect on nasal physiology, initiating an atrophic rhinitis progression. We emphasize that an adverse effect of nasal septal perforation begins with a disorder in air heating and moisturizing. Cold and dry air leads to crusting, increasing the size of the perforation and contributing to the mucosa's atrophy. Therefore, over time, nasal septal perforation becomes symptomatic and, according to modern concepts, is indicated to surgical reconstruction.

In conclusion, we would like to quote the famous Meyer's statement: "Nasal septal perforations must and can be closed," the title of his article published in 1994.[11] We emphasize that an adverse effect of nasal septal perforation begins with a disorder of air heating and moisturizing, and believe that a nasal septal perforation must and can be closed as early as it is possible.

## Competing Interests

The authors declare that they have no competing interests.

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