An investigation on airflow in pathological nasal airway by PIV

Kim, S. K.*1 and Haw, J. R.*2

*1 Dept. Mechanical Eng., Konkuk University, 1 Hwayang-dong Kwanggin-ku Seoul, 143-701, Korea.
E-mail: sungkim@kkuc.konkuk.ac.kr
*2 Dept. Materials Chem.& Eng., Konkuk University, 1 Hwayang-dong Kwanggin-ku Seoul, 143-701, Korea.

Received 18 July 2003
Revised 15 April 2004

Abstract: Understanding of airflow characteristics in nasal cavity is closely related with the physiological functions, like air-conditioning and smelling, and pathological aspects in nasal breathing. Several studies have utilized physical models of the healthy nasal cavity to investigate the relationship between nasal anatomy and airflow. The next step on this topic is naturally studies for disordered nasal airways and this is the main purpose of this article. Airflows in the pathological nasal airways, including nasal cavity and upper pharynx, of Korean adults are investigated experimentally by PIV measurement technique and air resistance measurements. Quantitative data for normal and pathological nasal airway are obtained. Average and RMS velocity distributions are obtained for inspirational and expirational nasal airflows. The CBC PIV algorithm with window offset is used for PIV flow analysis. PIV measurements of nasal airflow for nasal cavities with 50% and 70% adenoid vegetation are conducted for the first time. The asymmetric nasal cavities, due to either congenital deformity or injury, are also investigated. Comparisons in nasal airflows for both normal and abnormal cases are also appreciated and airflow characteristics that are related with the abnormalities in nasal cavity are proposed.

Keywords: Bio-Fluid Flow, Nasal Air Flow, PIV, CT (Computed Tomogram), Adenoid Vegetation.

1. Introduction

Knowledge of airflow characteristics in nasal cavity is essential to understand the physiological and pathological aspects of nasal breathing. Therefore, many medical and biomechanical researches have investigated on nasal airflow. Several studies have utilized physical models of the nasal cavity in an effort to understand the relationship between nasal anatomy and the distribution of inspired and expired airflow. Among others, Scherer et al. (1989) measured airflow rate in a large (20 times) model, constructed from computed tomograms (C.T), using a hot-wire anemometer (HWA). Hess et al. (1992) reported flow visualization results of dye-streak photos. Their model was made of clear silicone through casting in a death body. Hopkins et al. (2000) recently established a procedure to construct a transparent rectangular box containing a model of the nasal cavity for PIV measurement by combination of the Rapid Prototyping (RP) and the curing of clear silicone. In authors’ previous paper (Kim et al., 2002a), airflows in the normal nasal cavities of Korean are investigated experimentally by PIV measurement. (Kim et al., 2002b)

The next step on this topic is naturally studies for disordered nasal airways and this is the main purpose of this article. Two pathological airway cases, one with Adenoid Vegetation and the asymmetric nasal cavities due to either congenital deformity or injury are investigated by PIV. The CBC PIV algorithm (Hart, 2000) with window offset is used for PIV flow analysis. Creating the
accurate transparent flow passages is essential to analyzing the flow inward a complex flow passage by PIV. With dense CT scan data (166 data with 0.6mm scan thickness) and careful surface rendering, more sophisticated nasal cavity model can be made and used in this article.

Comparison of airflows for a normal and a disordered nasal cavity are appreciated. Adenoid vegetation exceeding 60% causes a rapid increase in pressure drop between nares and nasopharynx. The PIV results confirm this fact through the comparison of flow characteristics and RMS quantities at nasopharynx between models of 50% and 70% adenoid vegetation. One case of an asymmetric nasal cavity due to bent of nasal septum is dealt in this study. Even though the geometries of left and right cavities are quite different, flow rates of both cavities are almost even in this case. This can be explained by the fact that this patient’s nose adapts itself to this circumstance by deforming the other parts of nasal cavities.

The paradigm established in this paper can be applied to many kinds of otorhinolaryngological diseases and is believed to contribute to the diagnosis and treatment including medical operation of nasal diseases.

2. Flow passage inside nose and nasal anatomy

A brief nasal anatomy, related with the analysis on nasal airflow, is depicted in Fig. 1. Two nasal cavities are separated by a nasal septum. A nasal airway is mainly composed of three hooked passages (inferior, middle, superior airway) enclosed by nasal septum and inferior, middle, superior conchas: Green colored section in Figs. 1(b, c). In a state of relaxation, one of nasal cavities is used alternately for a period of hours. Most flow rates are believed to pass through the middle and inferior miatuses. Usually, parts of the passage can be blocked or bent by disease or injury. Therefore, having consulted with an otorhinolaryngologist, CT scan data of a Korean adult after modification in computer graphic is adopted as the nasal cavity model.

Among otorhinolaryngological diseases for children, the adenoid vegetation is one of the most frequent, and which causes the breath difficulty. General symptoms are the tendency of mouth breathing caused by a blocked nose, incorrect pronunciation, etc. For a flow passage of a nasal cavity with adenoid vegetation, 50% and 70% in cross-sectional area are removed from a replicate model of normal cavity under an ENT doctor’s advice, as shown in Fig. 2. The asymmetric nasal cavities, due to either congenital deformity or injury, are very popular. Sometimes this deformity becomes critical turn, results in the medical surgery. Figure 3 depicts a sample of CT scan data for an asymmetric nasal cavity. Airflows in each cavity are compared.

![Sagittal view of nasal anatomy](image1)

![Coronal view (CT)](image2)

![Selected coronal CT scan data](image3)