SIMULATION ON AIRFLOW INSIDE THE NASAL CAVITY WITH AND WITHOUT UNCINATE PROCESS

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ABSTRACT

Functional Endoscopic Sinus Surgery (FESS) is proposed for people with chronic sinus problems who do not respond to medical therapy. During (FESS) procedure, removal of uncinectomy is necessary. Excision of the uncinate process (UP) is to open the maxillary sinus orifice. The UP is a small structure bone in nasal cavity and it's located under the middle turbinate membranes. However, some patients have claimed that the (FESS) process has reduces their smelling capabilities and voice impairment. Due to this, this study is focusing the effect of changes airflow pattern after remove the UP. The main objective of this study is to simulate, compare and analyze the flow properties inside the nasal cavity with and without UP. This simulation has been done with 3 different models of nasal cavity. The parameter for this simulation is 0.0075 m^3s^{-1} and 0.015m^3s^{-1} air flow rate at the inlet nostril and ambient pressure at the outlet throat. These simulation show positive result and this indicates that the removal of the UP will result smelling capabilities decrease and voice impairment.

ABSTRAK

Functional Endoscopic Sinus Surgery (*FESS*) dicadangkan untuk orang yang mempunyai masalah sinus yang kronik yang tidak mempunyai respon terhadap perubatan terapi. Semasa prosedur, penghapusan *uncinectomy* adalah sangat diperlukan. Penghapusan *uncinate process* (*UP*) adalah untuk membuka lubang sinus maksilaris. *UP* adalah tulang struktur kecil di dalam rongga hidung dan ia terletak di bawah selaput turbinate tengah. Namun, beberapa pesakit telah mendakwa bahawa pembedahan ini telah mengurangkan deria bau dan perubahan suara. Oleh hal yang demikian, tumpuan kajian ini adalah tertumpu kepada perubahan pola aliran udara selepas membuang *UP*. Tujuan utama dari penelitian ini adalah untuk mensimulasikan, membandingkan dan menganalisis sifat aliran dalam rongga hidung dengan dan tanpa *UP*. Simulasi ini telah dilakukan dengan 3 model rongga hidung yang berbeza. Parameter untuk simulasi ini adalah 0.0075 m^3s^{-1} dan 0.015 m^3s^{-1} dan lubang hidung inlet dan tekanan ambien tekak outlet. Simulasi ini menunjukkan hasil yang positif dan ini menunjukkan bahawa penghapusan *UP* akan mengakibatkan penurunan terhadap deria bau dan perubahan suara.

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LIST OF ABBREVIATIONS

UP	Uncinate Process
CFD	Computational Fluids Design
FESS	Functional Endoscopic Sinus Surgery
OMCs	Ostiomeatel complexes
CT	Computed tomography
3D	three-dimensional
RMS	Root Mean square
DPIV	Digital particle image of velucimetry

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Nowadays, we are facing with a various modern diseases. This is because, we are exposed to a variety of ways such as disease spreads through dietary imbalance, air pollution, viruses that spread and so forth. A disease that is quite popular among human diseases associated with nose. Among them is sinusitis, sinus disease, paranasal sinus cancer and so on. All of these diseases are very dangerous and complicated because it has occurred in the nose and head. The surgery will have a hard decision and complicated to finish it. A long time ago, nasal surgery has to operate through the nose to remove the cancer. However today, new modern medical surgery have developed new machine that can remove cancer in nose without operate through the face. They called Functional Endoscopic Sinus Surgery (FESS).

Endoscopic sinus surgery is performed for those people who sinuses have chronic or acute sinusitis that persists for greater than six weeks after maximum medical therapy. Functional endoscopic sinus surgery (FESS) differs somewhat from the conventional surgical approach to this problem in that it stresses a careful diagnostic workup to try to identify the underlying cause of the problem, frequently in the anterior ethmoid area, the area of the openings of the maxillary and frontal sinus. Sometimes, with endoscopic sinus surgery examined may reveal a problem that can't be found with another method. . The first step of (FESS) is excision of the uncinate process (UP) to open the maxillary sinus orifice (Eitan Yaniv, 1997). This is because; the UP is located at the beginning of nasal passage and removal of UP is necessary for entry into the interior of the nasal cavity. The UP is a small structure bone in nasal cavity and it's located under the middle turbinate membranes. In case, most patients claim that immediately after removal of UP, nasal airflow significantly improves. This sensation last as long as the maxillary sinus orifice remains patent.

The advantage of this procedure is that, in general, the surgery is less extensive, there is often less removal of normal tissues, and the surgery can frequently be performed on an outpatient basis without the necessity for nasal packing. In general, the techniques are similar to those utilized for an intranasal ethmoidectomy, however, better visualization is obtained during surgery by the use of endoscopes. The endoscopes also allow problems in other sinuses to be viewed directly and, in many cases, for diseased tissue to be removed.

1.2 PROBLEM STATEMENT

Until now, there is no strong evident whether the removal of UP will lead to post operative complications or not. Some patients however, have claimed that the process has decreased their smelling capabilities. Early postulation stated that the flow profile during respiration will be different for the nasal cavity with and without the UP. In addition, removal of the UP may influence the performance of smelling receptors in the nose as result of flow profile alterations.

1.3 OBJECTIVE

This research will focus on the two aims as follows:

i. To study the characteristic of airflow phenomenon inside the nasal cavity with and without uncinate process.
ii. To simulate, compare and analyze the flow profiles inside the nasal cavity with and without uncinate process.
iii. To relate the medical effect by removing the uncinate process.

1.4 SCOPE

The main scopes of this research are:

i. The percentage of uncinate process removal will be studied to see the effect on the flow profile inside the nasal cavity.
ii. The airflow phenomenon from the throat until the nostril will be obtained
iii. The inferior and middle turbinate must be considered impact in nasal cavity.
iv. Medical effect will be neglected. Only the difference of density, velocity and flow profile will be considered in this experiment.
v. The range of age patient is between 20 to 30 years old.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review past research related to the geometry in nasal cavity, mechanics of airflow, airflow profile and airflow characteristic in the human nasal airways.

2.2 ANATOMY

Understanding the anatomy of nasal cavity is important and its anomalies are important because it leads of imaging anatomy, which is needed to plan of constructing the model.

2.2.1 NASAL CAVITY

Nasal cavity is a large fluid filled space above and behind the nose in the middle of the face plays an important role in breathing. The nasal cavity is divided into a right and left passageway by a vertical fin called nasal septum. This cavity runs along the top of the palate (the roof of the mouth, the shelf that separates your nose from your mouth) and turns downward to join the passage from the mouth to the throat. Sinuses are cavities or small tunnels. They are called paranasal because they are around or near the nose. The nasal cavity and paranasal sinuses hélp filter, warm, and humidify the air you breathe. They also give your voice resonance, lighten the weight of the skull, and provide a bony framework for the face and eyes. According to Mygind and Dahl in its entirety consists of a 5cm high and 10 cm chamber long chamber (D.J. Doorly *et al.*, 2008). The internal walls opposite the nasal septum have ridges formed bone called conchae (turbinate) bones. Under and lateral to each turbinate are passages called the inferior, middle and superior. These turbinates disrupt the airflow, directing air toward the olfactory epithelium on the surface of the turbinates and the septum. Below of middle turbinate have a bone called uncinate process. This UP is a one of the structure bone in nasal cavity.

2.2.2 UNCINATE PROCESS

The Uncinate Process (UP) which form part of the anterior ostiomeatel complexes (OMCs), is one of the most important bony structure. The UP is acts as an air vent shield which is preventing direct inspiration of air into the maxillary sinus and protecting the egress of the mucociliary clearance. The UP is the first structure to be identified and surgically removed because it is located at central to Functional Endoscopic Sinus Surgery (FESS). The UP arises from the lateral wall and occasionally from the inferior turbinate and projects into the airway of nasal cavity.

2.2.3 MIDDLE MEATUS

Middle meatus located in posterior half of the lateral wall. In the middle meatus is rounded bulge call bulla ethmoidalis which is due to the middle ethmoidal air cell which is open or above it. The UP is formed on the floor and medial wall of the ethmoid (PL Dhingra, 1998). Figure 2.1 and figure 2.2 show the structure of lateral wall in human nose.

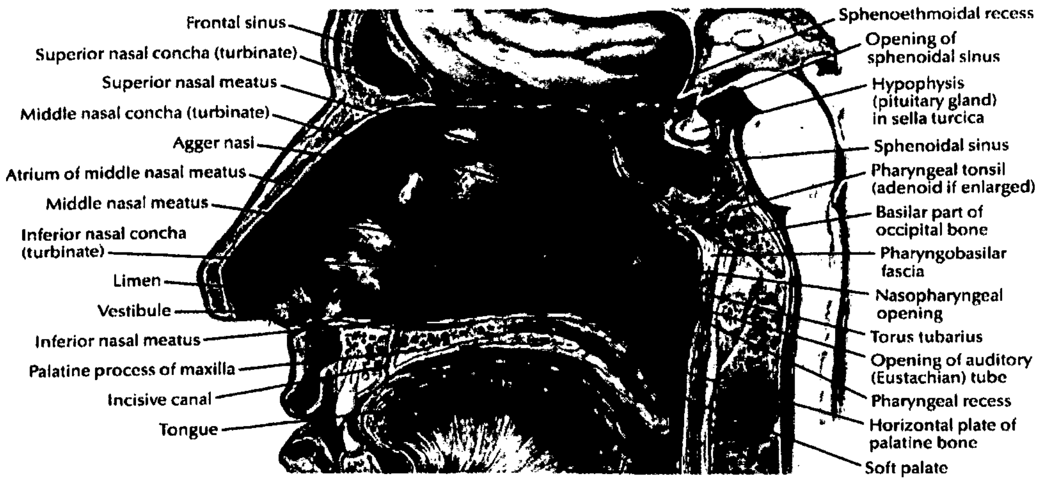

Figure 2.1: Structure of lateral wall of nose

Source: Dr. Wan Islah, (2010)

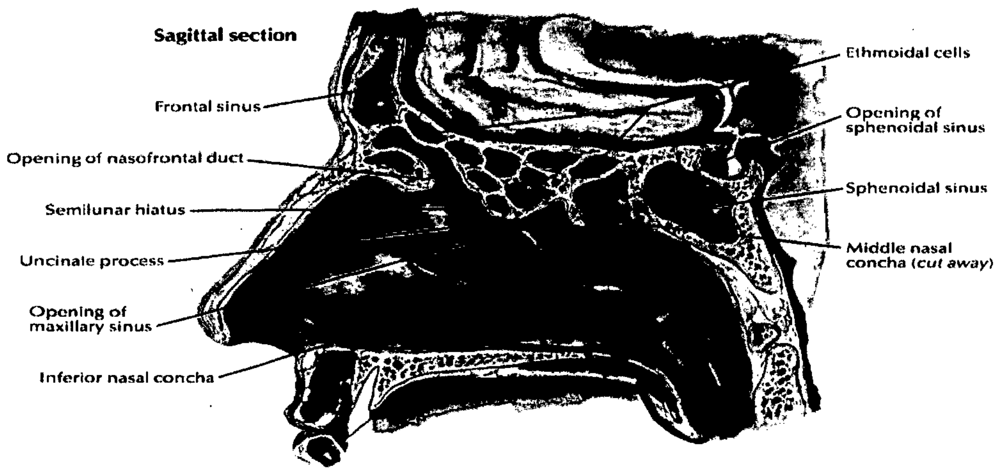

Figure 2.2: Lateral wall of nose with middle turbinate removed

Source: Dr. Wan Islah, (2010)

2.2.4 OLFACTORY MUCOUS MEMBRANE

Smell receptors is chemeoreceptors that are stimulated by molecules in solution mucus in the nose. The smell receptors are distance receptors and there is no neocortical projection area for olfaction. The olfactory receptors are located in a specialized portion of the nasal mucosa. The olfactory mucous membrane is constantly covered by mucus. The axons of the olfactory receptors neurons pierce the cribriform pate of the ethmoid bone and enter the olfactory bulbs. The olfactory neurons, like the taste receptors (William F. Ganong, 1999).

2.2.5 OLFACTORY NERVES

One of a pair of nerves associated with the sense of smell. They are composed of numerous fine filaments that ramify in the mucous membrane of the olfactory area. The fibers of the olfactory nerve are nonmedullated and unite into fasciculi that form a plexus under the mucous membrane and rise in grooves or canals in the ethmoid bone. The fibers pass into the skull and form synapses with the dendrites of the mitral cells. The area in which the olfactory nerves arise is situated in the most superior part of the mucous membrane that covers the superior nasal concha. The olfactory sensory endings are modified epithelial cells and the least specialized of the special senses. The olfactory nerves connect with the olfactory bulb and the olfactory tract, which are components of the part of the brain associated with the sense of smell. Figure 2.3 shows the located of the olfactory bulb in human nose.

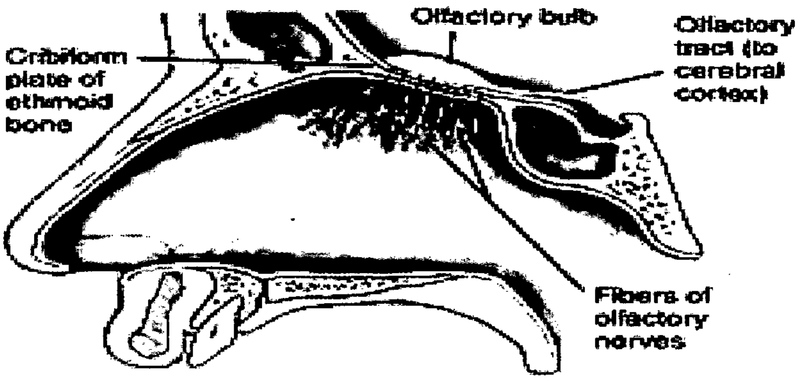

Figure 2.3: Lateral nose with olfactory nerves

Source: Mosby's Medical Dictionary, 8th edition, {2009)

2.3 NASAL CAVITY GEOMETRY

A nasal cavity was obtained with computer tomography (CT) scan. CT scan will capture outlined slices in the X-Y pane at the different position along the Z axis from the entrance of nasal cavity to anterior of the larynx at interval 1-5mm. The image sectioned scans were imported with modeling program software called GAMBIT into a 3D image. This software will created a smooth curve that connected point on the other coronal section (S.M Wang *et al.*, 2009). Image from CT scan also can be process with MIMICS software. Mimics is an image processing software package for 3D design and modeling. Mimics generates and modifies surface 3D models from stacked medical images such as CT scan, Confocal Microscopy, Micro CT, and Magnetic Resonance Imaging (MRI) through image segmentation done in the STL format. From the segmented image, data captured by CT scan, a surface triangular mesh that modeled the surface of the nasal cavity. The mesh was use as input to the volume grid generator and to comply with a set of constraints and quality measures dictated by the grid generator and the CFD software (M. Kleven *et.al.*, 2005).

An anatomically correct replica model with inferior and middle turbinate is constructed. The superior turbinate is neglected where it is always vestigial in the average human nasal passage. The anatomical middle turbinate will be denoted as upper turbinate and the inferior turbinate as lower turbinate. The geometry of the nasal cavity includes besides lower and upper turbinate also cartilage spurs. These are illustrated together with a coronal cross section. The real nasal geometry has been extracted from a CT scan data set. A centered cube, enclosing the complete geometry, generates an initial grid. The grid is repeatedly refined and newly generated grid cells, which do not occur inside the geometry. An alternating digital tree algorithm (ADT) does the refinement (I. Hörschler *et al.*, 2009). Figure 2.4 and figure 2.5 show the constructed of real and simplified 3D nasal cavity model.

Figure 2.4: 3D model of the real nasal cavity

Source: I. Hörschler *et al.*, (2009)

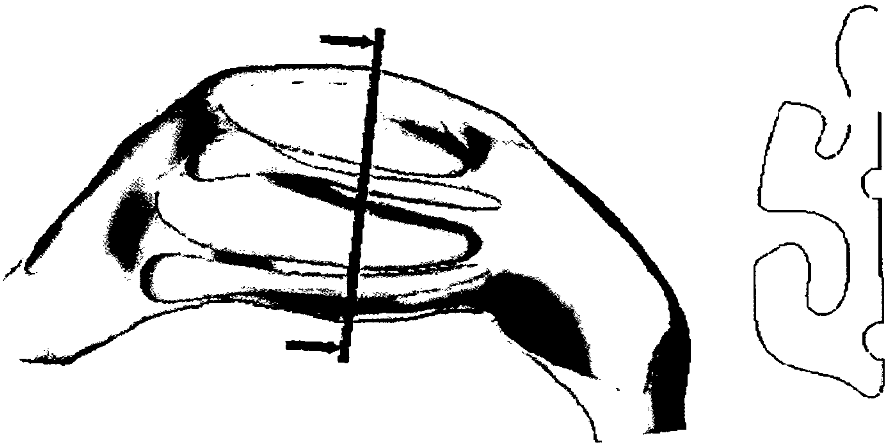

Figure 2.5: Simplified of 3D nasal cavity model with coronal section

Source: I. Hörschler *et al.*, (2009)

2.4 STANDARDIZED GEOMETRY OF THE HUMAN NASAL CAVITY

A standardized geometry of human nasal cavity was created by aligning and processing 30 sets of computed tomography (CT) scans of nasal airways. The 3D geometries of the single 60 single human nasal cavities were generated from the CT scans. The measurements of physical parameters of each single nasal cavity were performed. A methodology was developed to scale, orient and align the nasal geometries, after which 2D digital coronal cross sectional slices were generated. (Y. Liu, M. R. Johnson, E. A. Matida, S. Kherani, and J. Marsan, 2009). Table 2.1 show the data collection of CT scan from various person.

Table 2.1 Subject and CT scan information for 30 individuals in current study

Subject No.	Sex	Age	Distance Between Slices, mm	Resolution in *x-y* Plane, mm/pixel	Number of Scan Planes
1	F	45	2.5	0.325	38
2	M	59	2.5	0.325	40
3	F	63	2.0	0.24	39
4	F	36	2.5	0.325	38
5	F	20	2.5	0.325	40
6	F	49	2.0	0.325	36
7	F	30	2.5	0.325	32
8	M	74	2.5	0.325	43
9	M	60	2.5	0.325	42
10	F	17	2.5	0.325	39
11	M	56	2.5	0.325	40
12	M	52	2.5	0.325	44
13	M	39	2.5	0.325	40
14	F	37	2.5	0.325	38
15	M	52	2.5	0.3	43
16	M	41	2.5	0.293	39
17	F	78	2.5	0.339	43
18	F	26	2.5	0.245	41
19	M	52	2.5	0.283	42
20	F	23	2.5	0.313	44
21	M	52	2.5	0.325	39
22	F	45	2.5	0.325	34
23	F	52	2.5	0.325	38
24	F	30	2.5	0.325	45
25	F	34	2.5	0.325	41

26	F	66	1.0	0.348	80
27	F	49	2.5	0.325	42
28	M	36	2.5	0.325	40
29	M	42	2.5	0.293	47
30	M	45	2.5	0.293	40
Average		45.3	2.42	0.315	41.6
Median		45	2.5	0.325	40
Max		78	2.5	0.348	80
Min		17	1	0.24	32

M, male; F, female.

Source: Y. Liu, M. R. Johnson, E. A. Matida, S. Kherani, and J. Marsan, (2009)

2.5 NASAL AIRWAY BOUNDARY

In reality, model of nasal cavity are very complicated. The airways boundary is time varying, possibly compliant at elevated flow and covered for the most part by a thin film of mucus (M. Kleven *et.al.*, 2005). The structures outside of the nasal cavity itself affect the flow dynamic during respiratory where the shape of the external nose influence flow entering the nares. During the expiration, the exhaled flow will impressed the airways geometry below the nasopharynx. Until today, no model has yet completed with all these features. The flow is considered as a laminar flow through a confined geometry that is representing a nasal cavity. Boundary conditions are therefore required along the cavity walls and at the inflow and outflow boundaries as well. These are the assumptions of the physiological conditions. These conditions are in principle periodically in time with changing main flow direction for inspiration and expiration. The flow can be assumed quasi-stationary according to the breathing frequency is sufficiently small (M. Finck *et al.,* 2007).

2.5.1 STEADY STATE BOUNDARY CONDITION

A no-slip isothermal condition with $T_{wall} = T_{\infty}$ and a zero pressure gradient normal to the wall are imposed on the wall. The 1-Dimensional energy equation for compressible, isentropic flow can be used in a modified form at the inflow boundary to interactively compute the static pressure from the given value of the velocity distribution. The quantity of velocity distribution is an integral value for the inflow cross section such that the actual velocity distribution has to be prescribed as an additional condition by assuming a fully developed flow. On the outflow boundary, the static pressure level is imposed (I. Hörschler *et al.*, 2009).

2.5.2 UNSTEADY BOUNDARY CONDITIONS

The conditions on the wall are no slip, isothermal and zero normal pressure gradient, still hold in time-dependent flows. To mimics the unsteady flow of the human respiration cycle respiration is understood as an isentropic expansion from a steady ambient state with stagnation pressure for the inflow boundary at the nostril. At expiration, the outflow and inflow boundaries are exchange. That is, expiration the throat boundary is the inflow boundary. As isentropic expansion from a steady state is generated through a time dependent stagnation pressure in the throat, where as a constant pressure at the nostril (I. Hörschler *et al.*, 2009).

2.6 CHANGES OF NASAL AIRFLOW

Changes in the nasal air were studied for pathologic conditions such as the presence of polyps, swelling, atrophy or resection of tubinates, and for enlarged adenoids (Tonndorf, 1939). The presence of polyps in the superior meatus, and generalized swelling of the turbinates seem to have the most effect on airflow pattern. The effect of various kind of turbinectomy on nasal airflow of great interest to rhinologists who must consider such aspects of surgical treatment prior to treating nasal obstruction (Seung-Kyu Chung, 2008).

2.6.1 MIDDLE TURBINECTOMY

The middle turbinate is located in the anterior portion of the middle nasal airway and its shape is thought to have an important influence in nasal airflow. The exact shape and size of the middle turbinate not indentified yet but it may be reshaped partially during endoscopic sinus surgery. By using DPIV methods, it can be measures the changes of nasal cavity by using three different models of turbinectomy. There are partial, anterior partial and total middle turbinectomy (Kim and Chung, 2004). The airflow through the upper airway including the middle meatus was increased in that three-turbinectomized model. The airflow was identified in term of RMS velocity. However, there are different results showing that the middle turbinate did not influence the overall flow pattern during expiration and inspiration with numerical and DPIV studied using schematic nasal cavity models (Hörschler et al., 2006; Kim and Chung, 2008). The RMS velocity is consistently increase after the turbinectomy with the occurrence of eddies following atrophy or for a resected middle turbinate in nasal cavity (Torndorf, 1939; Kim and Chung, 2008).

2.6.2 INFERIOR TURBINECTOMY

Many turbinate procedures are done worldwide to enlarge the valve area and the inferior airway because of the enlargement of the inferior turbinate is considered as a major cause of nasal obstruction. The DPIV method was used to investigate the effect of three kind of inferior turbinectomy – partial, anterior partial and total inferior turbinectomy on nasal cavity. the main airflow through the middle airway, including the middle meatus, was not overly different between the two partial turbinectomy models. The main pathway of airflow in the totally resected model was altered in the middle and inferior airways and the lateral portion of the enlarged airways was filled with very low flow that was indicative of eddies. The RMS velocity was increase in the two partially operated models. In the total inferior turbinectomy model, the lowest airway was not used as effective air tract. The inferior turbinate and spurs seemed to serve a guide vane to ensure a homogeneous velocity distribution in the nasal cavity channel. In the total resection of the inferior turbinate, the airflow was characterized by massive vortices that impacted ion flow distribution in the nasal cavity (Hörschler et al., 2006; Kim and