Odiosoft-Rhino: Nasal Sound Analysis

Nasal airflow

The predominant respiratory airflow regime in human airways is neither laminar nor turbulent, but a regime of varied disturbances termed transitional and not amenable to simple mathematical description.[1] Turbulence generates sound waves that can be heard. [2] Because higher velocities enhance turbulence, audible sounds resulting from turbulence become louder whenever nasal respiratory flow is increased across narrowing nasal passage where the turbulence is occurring.

Airflow through the nose follows the basic physical laws of fluid flow. According to Kimmelman, mathematically by the use of Poiseuille’s law. [3]

$$V = \triangle P \pi r^4 / 8 \eta L$$

Where V is the nasal airflow rate in liters per second, **r** is radius of the passageway (nasal vault), is the coefficient of viscosity, **L** is the length of the passageway, η is the coefficient of viscosity, and $\triangle P$ is the change (drop) in pressure. The formula applies only to laminar airflow, and disordered or turbulent flow occurs if the flow rate (V) exceeds the value of 2000. The number, or ***Re,*** describes the conditions under which turbulent flow occurs:

$Re = aV\rho/\eta$, where is the diameter of the passageway and p is the fluid density. A value exceeding 2000 predicts turbulent flow,

$$\triangle P = R \cdot V$$

When the flow is turbulent, as may occur with a deviated nasal septum or other impingement into the airway (similar to a bend or rock in a stream), a sensation of obstruction may occur and relationship becomes [4] $\triangle P = R.V^2$

Moreover, according to Poiseuille's law, as the radius of the tube increases, the flow increases to the fourth power. Finally, tubes that are irregular, such as the nose, cause turbulent flow. When air passes through the nose, the flow is regulated by four values: the external valve, the internal valve (the angle formed by the junction of the upper lateral cartilages and the septal cartilages are the most important), the nasal turbinates, and the septum. [5]

What is FFT?

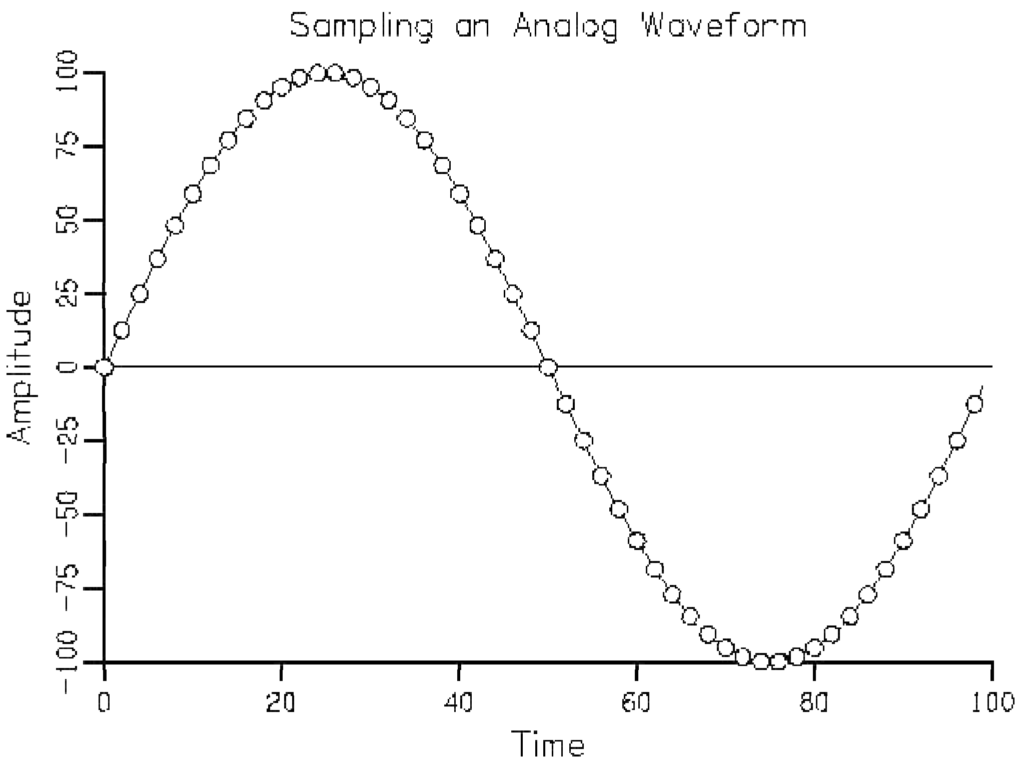
Fourier transform was discovered by a French mathematician and scientist, Fourier, as a natural progression of his Fourier series theory. The Fourier series theory states that any waveform, however complicated, can be expressed as a series of two or more simple sine waves and cosine waves, if the waveform is periodical, that is, composed of the same repeated waveforms. The mathematical expression of this theory is called Fourier series. Fourier transform involves expansion of the Fourier series from $-\infty$ to $+\infty$ and developed. It is not always clear the extent to which a signal can be actually measured and determined as periodical, especially when measuring the waveform up to infinity, as it becomes fainter and fainter. Thus, in general, only a part of the observed waveform is cut out and Fourier transform performed on this period of the waveform assuming that the waveform pattern is infinitely repeated. Originally, this Fourier transform calculation required a tremendous number of multiplication calculations. However, J.W. Cooley and J.W. Tukey proposed a method of calculation that reduces the number of individual calculations by taking the number of data items as equal to 2^n. If the number of data items is assumed to be 1024, the number of multiplications, that is 1024 x 1024 = 1048576, is reduced to 10240. This method was called Fast Fourier Transform and is often referred to by its acronym, FFT.

Digitized Sound

Digital waveforms are sampled functions of time, described in terms of their sampling rate in *Hertz* and sample resolution in *bits* per sample. The term *Hertz*, abbreviated *Hz*, normally means *cycles per second* when describing waveforms, but it is generalized to *samples per second* when describing a sampling rate. Each sample in a digital waveform is a measurement of the amplitude of an analog waveform at an instant in time. The sampling rate specifies how many measurements of the analog signal amplitude are made per second by the Analog to Digital Converter (ADC) hardware of the computer. Similarly, when digital waveforms are converted to analog signals (using a Digital to Analog Converter or DAC), sampling rate refers to how many times per second the (DAC) hardware must be updated with a new sample value.

Sample resolution specifies the accuracy of each amplitude measurement made by the ADC hardware. The more *bits* of resolution, the greater the accuracy. A *bit* is defined as one binary digit, that is, either the value 0 or the value 1. Thus, when only one bit is used to represent the value of an amplitude measurement, the amplitude must be either 0 or 1. If two bits are used to represent amplitude values, then four possible amplitude values can be represented (0, 1, 2, and 3). More generally, the number of amplitude values that can be reresented by a given number of bits is 2**N where N is the number of bits. Using a large number of bits per sample allows the full amplitude range of an ADC to be partitioned into a large number of very small steps.

In the following figure, the X axis is time in msec and the Y axis is amplitude in arbitrary units. This figure shows an analog sine wave (solid line) is sampled (illustrated by the circle symbols) at a comparatively high rate compared to its frequency and with good sample resolution.



Odiosoft-rhino Software

We used software program called "**Odiosoft-rhino**" for analyzing of the sound waves using the fast Fourier transform (FFT). The software was developed by me. We easily calculated sound intensity and sound frequency of nasal sound by help of this new software program. We created a new descriptive parameter to characterize the frequency spectrum, as subsequently described. I used the following parameters:

Low frequency (500-1000 Hz),

Medium frequency (1-2 kHz),

High frequency (2-4 kHz, 4-6 kHz).

The methods of nasal sound recording:

1) The patient must be relaxed
2) I identified the artifacts such as rubbing sounds of the microphone cable or over modulation of the amplifier, and removed them with help from spectrogram overview FFT. Four consecutive expirations were held, and then the most suitable one was chosen from every recording.
3) Before starting the test all crusting and mucous must be removed.
4) Right side of the nose is performed the test, thump finger of left hand closes left nostril of the nose. During the test, the prope at the right hand is held parallel to right nasal cavity. The nasal prope must not be inserted into the nasal cavity, it must be 1 cm far away the nose. And the test starts. Before the test, deeply breaths are made two or three times. Then breathe is hold by the patient. During non forced nasal expiration the record starts. The breath expiration must be normal and non forced, it mustn't be a forced or a spaced expiration. Then this same procedure is applied to the other nose. The equipment which is used in this study is seen in picture 1.

Note: The room where the nasal sound analysis is applied must be quiet. During the test, artifact sounds such as rubbing sound of the microphone cable, background noise and computer fan noise affect the test results. The nasal sound samples including these artifact sounds must be removed while evaluating. Besides, nasal recording time must be at least 1 second. Shorter recordings do not provide accurate results for the analysis. Because of all these reasons, four consecutive inspirations of each subject were recorded and technically the most suitable of these was chosen.

Picture1

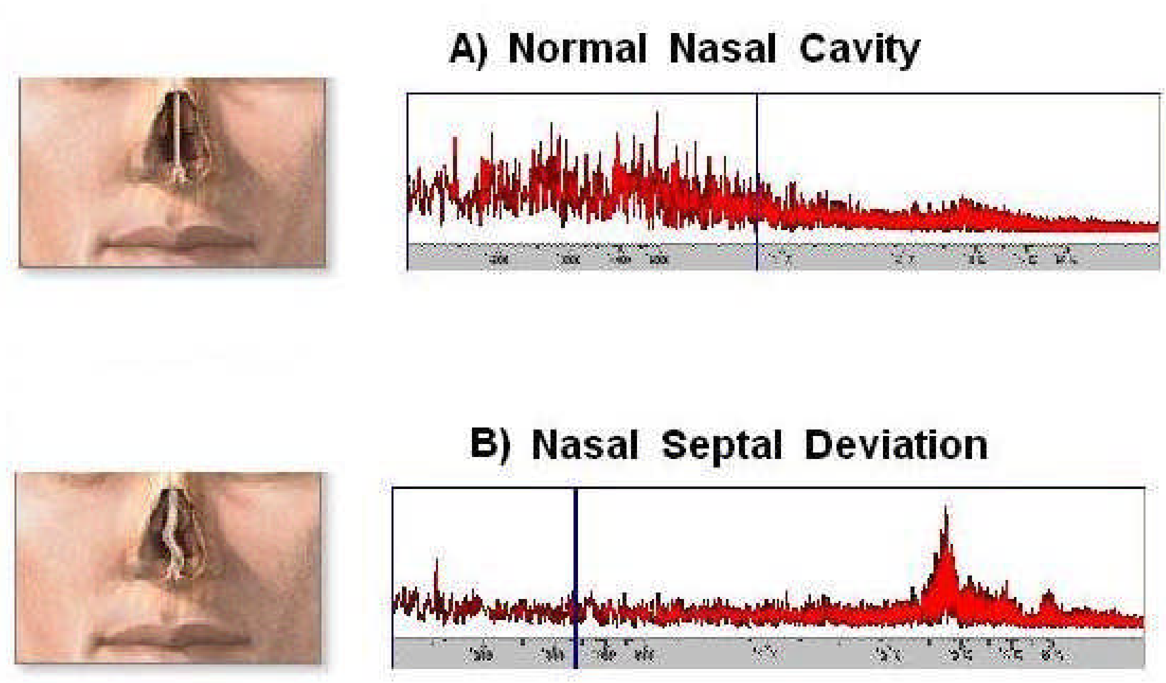
<u>Nasal sound analysis</u>

As air enters this constricted segment of the airway, acceleration of the airflow occurs. This conduction affects the pattern of nasal airflow and transforms the turbulent pattern of it.[6] This turbulent airflow causes louder nasal sounds. [2] Sound wave spectra are clearly linked to respiratory airflow rate. Sound increases with the air flow, engendering a marked upward shift in frequencies in the spectra. [7] I defined the analysis of nasal sound sample in another study [8], being a simple, an easy and noninvasive method for evaluation of nasal airflow. Other recent studies revealed that flow modifies both the intensity and the frequency distribution in the spectrum. [9-11] However, The mean amplitude and the mean frequency are increasing functions of the flow. [11, 12]

Effect of Nasal Septal Deviation on Nasal Airflow Pattern

Nasal septal deviation makes narrowing in nasal cavity and decrease cross-sectional area of it. This condition makes increase in velocity of nasal airflow and transforms it from a laminar pattern to a more turbulent pattern. [5,6] Turbulent flow produces nasal sound waves. Nasal sound frequency and intensity increases with the turbulent air flow, engendering a marked shift upward in frequencies in the spectra. [7] The nasal sound intensity at high frequency increases proportionally related to the degree of the patients with nasal septal deviation.

In the patients with nasal septal deviations the sound intensity was low at lower (500-1000 Hz) and medium frequencies (1-2 kHz).This results were statistically significant. However the sound intensity was higher at high frequencies (2-4 kHz, 4-6 kHz). A proportional relation was found between the degrees of septal deviation and sound intensity increase.



Effect of nasal valve area on inspirator nasal sound spectra

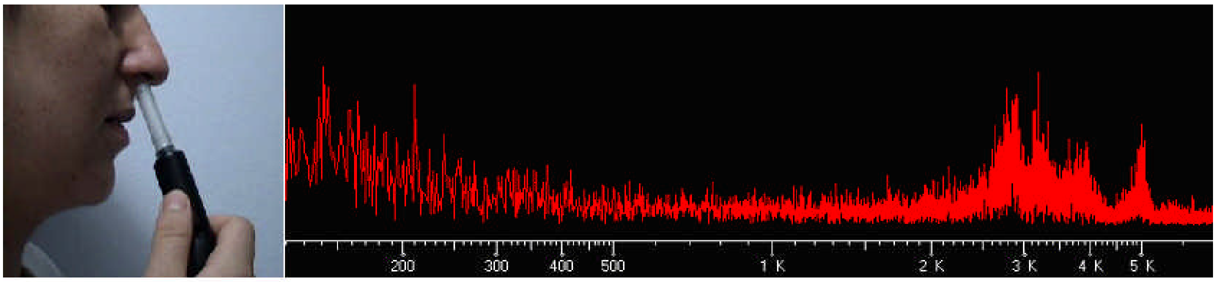
The nasal valve area plays an important role in the transformation of the nasal airflow from a laminar pattern to a more turbulent pattern. This condition affects nasal sound spectra and produces a marked shift upward in frequencies in the spectra. “Cottle maneuver” causes to the dilatation of the nasal valve area.[13] Therefore, nasal cross-sectional area increases, which may lead to the increase of nasal airflow velocity. Airflow transforms the turbulence into laminar and the sound intensity level at high frequency decreases in the sound spectra.

We have found an increase in sound intensity at high frequency in the sound analyses of the patients without the “Cottle maneuver”; whereas, a decrease in sound intensity at high frequency was found in patients with the “Cottle maneuver”.

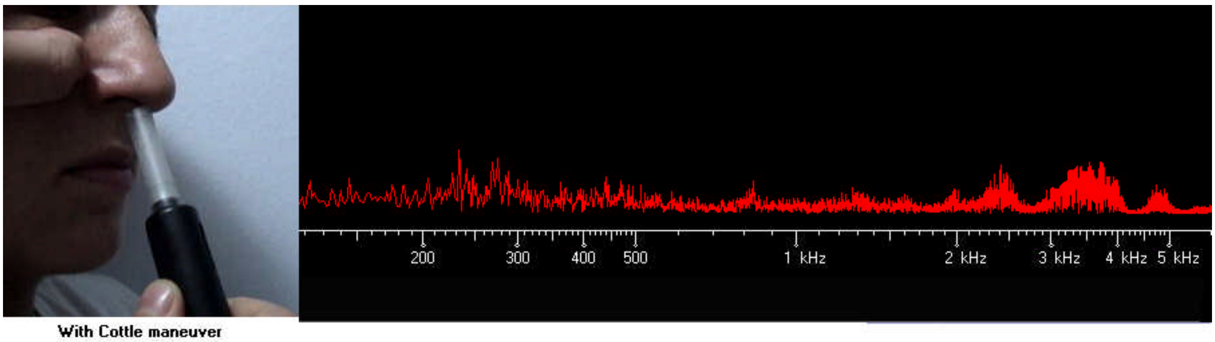
İnspiratuar nasal sound recording

1) The patient must be relaxed and before starting the test all crusting and mucous in the nasal cavity must be removed.
2) While testing on the right side of the nose, the thumb of the left hand closes the left nostril of the nose. During the test, the probe in the right hand is held parallel to the right nasal cavity. The nasal probe must not be inserted into the nasal cavity; it must be 1 cm far away from the nose. Before the test, the subjects must take two or three deep breaths. The recording starts during non forced nasal inspiration. The same procedures are repeated by applying “The Cottle maneuver” to the same nasal cavity. This maneuver involves pulling the patient's cheek laterally, which opens the nasal valve angle. Then, this same procedure is applied to the other nostril.

Application of nasal prope



Inspiratory nasal sound analysis (without Cottle maneuver)



Inspiratory nasal sound analysis (with Cottle maneuver)

Web based nasal sound analysis: A new diagnosis

In this technique, patient test data collected in the home or office could be automatically collected, analysed and inserted directly into an electronic patient record to be reviewed at the next consultation without coming to the hospital. We are investigating the integration with nasal sound analysis and web technology, both for communication and for management of web-diagnosis. This new system is aimed to give information to the patients and to get pattern about the nasal airflow of the patients via internet by help of web based nasal sound analysis as postoperative course.

The methods of nasal sound recording

1. The patients recorded their expirium sound in the nasal cavity with the microphone and with the demo software program called ***web-add*** in the computer at home or in the office. They sent us them as a wav file in e-mail (Figure2). The patients sent the nasal sound in both cavities by recorded them three times. Three consecutive expirations were held, and then the most suitable one was chosen from every recording.

2. Performance of the sound card must be good. The peak level (***PL***) is calculated by the program which is ready in the "odiosoft-rhino" program to analysis performance of the sound card. ***PL*** is a maximum value of noise amplitude. We accepted good the computer ***PL*** values of the sound card performance below 10 dB. The testing room had a background noise level very low.

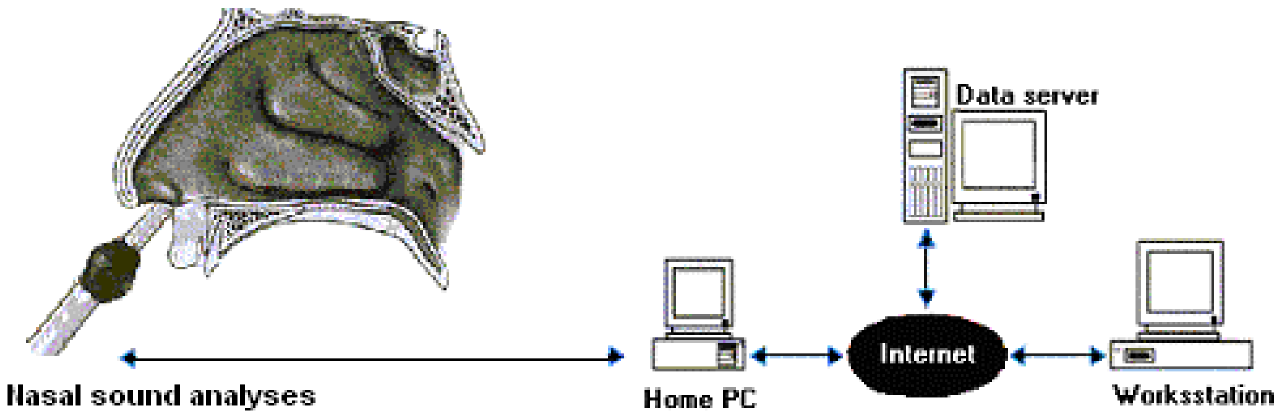


Figure2. Schematic diagram of web based tele-diagnostic system for the management.

<u>The advantage of Odiosoft-rhino:</u>

1) This method easily provides to analyze the nasal expiratory sound spectra with Fast Fourier Transform (FFT) technique.
2) It presents the degree of anatomical obstruction of nasal cavity and biophysically features of nasal airflow.
3) Non invasive methods, it is very easily applicable for clinical study.
4) It is portable and does not require more equipment.
5) Low cost
6) This method may be a new way of evaluating the nasal valve area.
7) Web Based Nasal Sound Analysis will be an important method to follow the postoperative course and the nasal airflow evaluation. By this way the new method will save time and money providing the patients not to come to the hospital unnecessarily. It also decreases the health cost.

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Dr.Erdal Seren

Giresun, Turkey

e-mail: eseren@yahoo.com

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