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# Optimal sample frequency in computerized rhinomanometry. Development and method

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## SUMMARY

*The authors studied the pressure/flow signals generated during active anterior rhinomanometry of 25 subjects, presenting a normal transnasal breathing. By means of a Fourier transformation, the frequency content of these signals was analyzed. This investigation demonstrated clearly that signals with a frequency of more than 50 Hz no longer yield any further information about the transnasal ventilation.*

## INTRODUCTION

The aim of the study was to investigate an important characteristic in data acquisition in computerized rhinomanometry, such as the sample frequency. This was done because many investigators use different sample frequencies in their data acquisition, without clearly demonstrating or proving that the signals acquired at these frequencies, include all the information about the transnasal ventilation.

The same holds true for the many companies delivering tools and included software, without explaining why they built in that specific sample frequency in their data acquisition programs.

## SUBJECTS AND METHOD

Twenty five adults, aged 20-50 years, were enrolled in the study (15 males, 10 females). Subjects gave no history of nasal problems and none suffered from an actual coryzal illness. Full rhinoscopic examination was performed upon all subjects and all had normal, unobstructed nasal airways.

For the experiments, the analog pressure and corresponding flow signals generated during active anterior rhinomanometry, were sampled at 200 Hz during 20 sec and digitized by a data-acquisition computer system (MASS-

COMP). This set-up was connected to the local UNIX network for mathematical processing and graphic representation of the results. A preliminary analysis of the frequency content of pressure/flow signals generated during AAR under normal conditions, was performed by a 'Fast Fourier transformation'.

A Fourier transformation is based on the superposition principle, which makes it possible to analyze complicated wave motions (such as rhinomanometrical pressure and flow signals) as a combination of simple waves with own frequency and amplitude as illustrated in Figure 1.

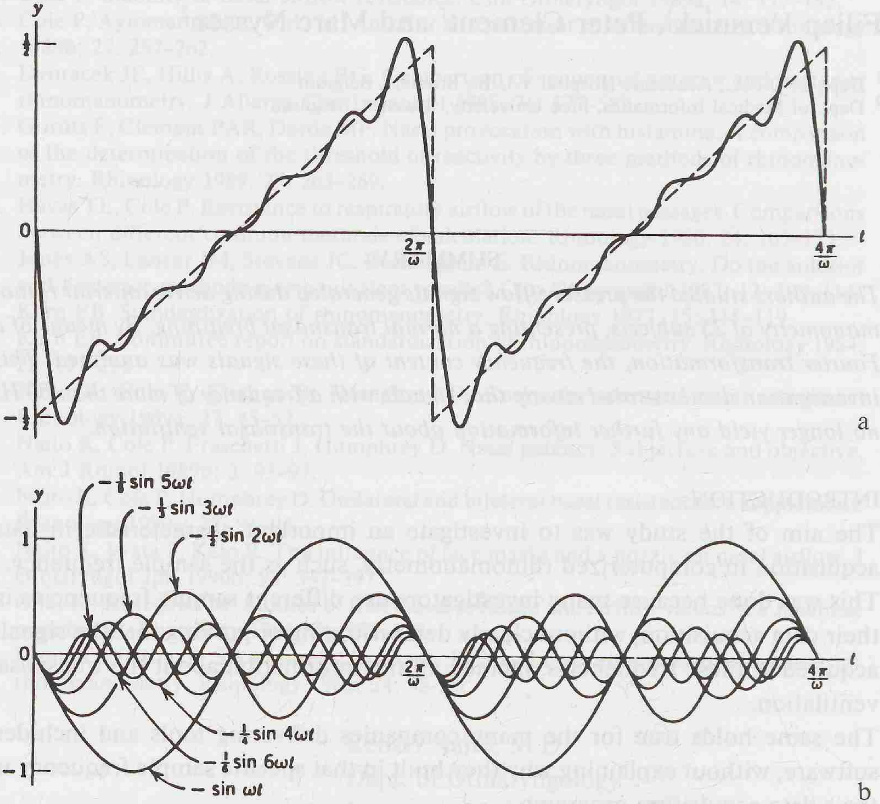

Figure 1. Illustration of the Fourier transformation principle (b) applied for analyzing complicated wave motions such as rhinomanometrical signals (a).

Although we were able to demonstrate that near 100 Hz, signals coming from the transnasal ventilation were becoming very small. According to the Nyquist criterion concerning data acquisition, the sample frequency was established at 200 Hz which seemed a safe range for further processing.

For each of the 25 tested individuals, pressure and flow data for each side of the nose were collected five times.

A Fourier transformation was done on all the data.

Next the five pressure and flow spectra for right and left side of the nose of each subject were summed and averaged, resulting in four averaged (or representative) spectra per subject (spectra for pressure and flow for the right and left side of the nose).

In a further step, the 25 representative spectra for pressure for the right side of the nose were summed and averaged, resulting in an over-all, averaged spectrum. The same was then done for the 25 representative flow spectra for the right side of the nose and 25 representative pressure and flow spectra for the left side. All these calculations resulted in four over-all spectra.

Together with the determination of the four over-all spectra, the lowest and highest values encountered in our test-population were calculated.

A last step in our mathematical processing consisted in a rearrangement of the four sets of spectral data into cumulative frequency distributions or analyzing spectral reconstruction percentages versus frequency cut-off.

## RESULTS

As illustrated in Figure 2, the over-all averaged spectrum for the pressure data for the right side of the nose, clearly demonstrates that the major part of signals, acquired during respiration are within 20 Hz with peak values within 5 Hz.

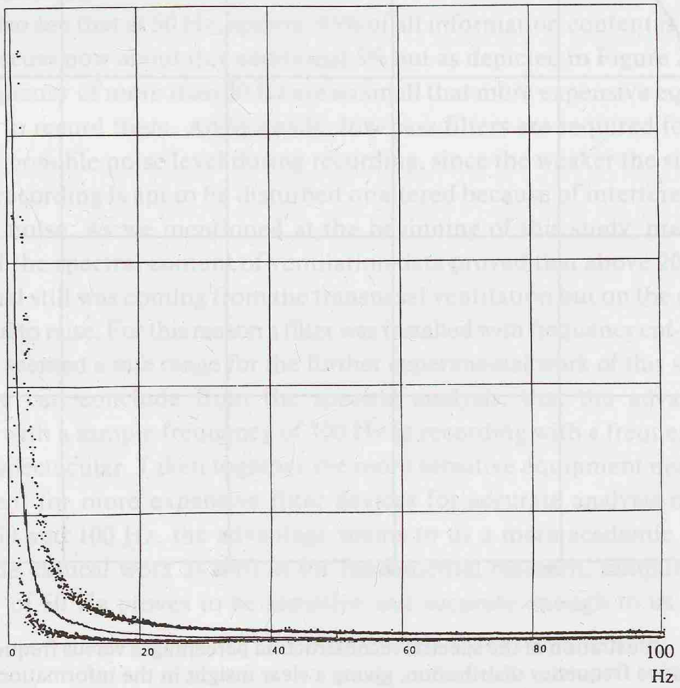

Figure 2. Resulting over-all spectrum for press for the right side of the nose (averaged, highest and lowest vatues). The spectra for flow for the right side and press and flow for the left side are identical.

Going through the whole spectrum (averaged, lowest and highest values) we see that from 50 Hz the amplitude of the simple waves, as analyzed by the Fourier transformation and being part of the more complicated wave forms such as rhinomanometrical signals, decreases to zero.

By rearranging the spectral data into spectral reconstruction percentages versus frequency cut-off or cumulative frequency distribution, as illustrated by Figure 3, we obtain a real insight in the information content of rhinomanometrical signals. One can see that within 20 Hz, 86% information is reached with regard to the averaged data while for the highest values 92% is reached and for the lowest values 79%. From 20 to 100 Hz there is only a very slight increase in information content, as illustrated by the slight slope of the curves, finally reaching 100%.

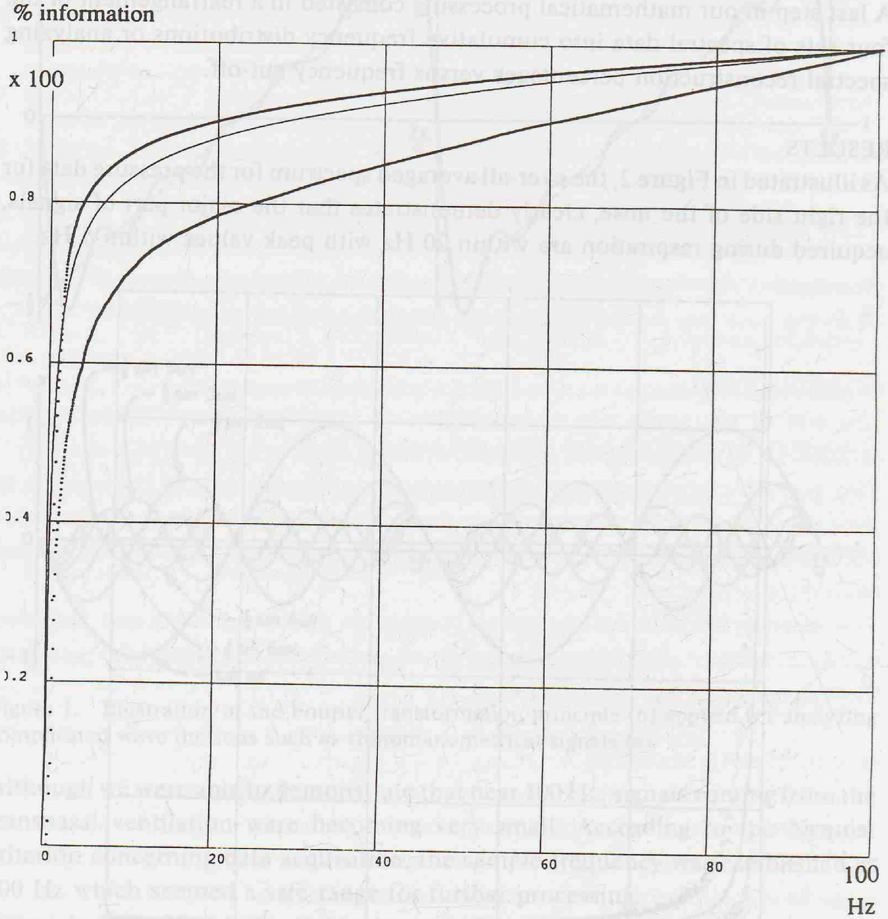

Figure 3. Illustration of the spectral reconstruction percentages versus frequency cut-off or cumulative frequency distribution, giving a clear insight in the information content of rhinomanometrical signals.

## DISCUSSION

In the actual clinical situation, a lot of studies with or on rhinomanometry are performed. However, hardly one word is mentioned about the reliability of the technique such as accuracy in the data acquisition, insight in the information content of rhinomanometrical data and even data processing.

Additionally, the authors found by reviewing the literature, a lack of fundamental studies on rhinomanometry as a technique.

Thirdly, there still exists a lot of disagreement concerning standardization among researchers as well as the companies furnishing rhinomanometrical equipment, in using different frequencies in their data acquisition programs.

Because of the rise in computerization in rhinomanometry, the authors studied an important fundamental characteristic in computerized acquisition of rhinomanometrical signals such as the sample frequency. Since the sample frequency is directly related to the information content of pressure/flow curves, they wanted to determine the frequency range within one can be sure that no information is lost.

In this study the evaluation of the frequency content, of both pressure and flow data over a population of test persons, was established by performing Fourier transformations on their data. As depicted in Figure 3, it is clearly seen that sample frequencies higher than 100 Hz, no longer offer any information about the transnasal ventilation.

One can also see that at 50 Hz, approx. 95% of all information content is reached. We can discuss now about this additional 5% but as depicted in Figure 2, signals with a frequency of more than 50 Hz are so small that more expensive equipment is needed to record them. Additionally, low-pass filters are required for having the lowest possible noise level during recording, since the weaker the signal, the more the recording is apt to be disturbed or altered because of interference with unwanted noise. As we mentioned at the beginning of this study, preliminary analysis of the spectral content of ventilation data proved that above 200 Hz, no single signal still was coming from the transnasal ventilation but on the contrary, noise began to raise. For this reason a filter was installed with frequency cut-off at 200 Hz, which seemed a safe range for the further experimental work of this study.

Finally we can conclude from the spectral analysis, that the advantage of recording with a sample frequency of 100 Hz to recording with a frequency of 50 Hz is not spectacular. Taken together the more sensitive equipment needed and requirement for more expensive filter devices for accurate analysis of signals between 50 and 100 Hz, the advantage seems to us a mere academic fact.

For routine clinical work as well as for fundamental research, sampling with a frequency of 50 Hz proves to be sensitive and accurate enough to us.

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