

EVALUATION AND SIGNIFICANCE OF RESPIRATORY ACOUSTICAL IMPEDANCE

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The acoustical input impedance of the respiratory system or Respiratory Acoustical Impedance (RAI), characterizes the dynamic relationship between airflow and the pressure at the mouth. It is established by a stimulus-response experiment: in the so-called "forced oscillation technique", the airflow, usually generated by a loudspeaker, is forced into the ventilatory system and acts as a stimulus. The pressure induced by this forced airflow is the response of the ventilatory system. If the system behaves approximately linearly, the relationship between the airflow and pressure may be described by a transfer function which, in this particular case, is the RAI. It is given usually by the frequency dependence of the real part (the *resistance*) and of the imaginary part (the *reactance*) of the impedance which is computed as a complex number. The frequency interval has usually been between 4 and 50 Hz. Generally, a *pseudorandom noise* is chosen as the stimulation. This contains all the frequencies of interest, and allows rapid determination of the frequency dependence of the RAI. Moreover, the use of a pseudorandom noise approximating a Gaussian white noise presents a real advantage for it constitutes the most comprehensive excitation signal, and even yields a description of the non-linear behaviour of the ventilatory system.

Typical alterations of the RAI are observed when the airways are partially or fully obstructed. This produces a characteristic decrease of resistance with increasing frequency below 20 Hz. It is accompanied usually by a lowering of the reactance. Simultaneously, the resonant frequency increases. This typical frequency-dependence of the resistance and reactance is the consequence of increased peripheral resistances. RAI measurements are useful for identification of various pathologies: acute pulmonary congestion following left ventricular failure [1], airways

responsiveness during bronchial inhalation challenges in asthmatic patients [2] and chronic obstructive disease [3].

Forward models (models based on lung anatomy and the computation of the fluid dynamic behaviour of the airflow in the bronchial tree and alveolar compartments) have been developed [3] and provide a good understanding of the frequency-dependence of the RAI. They allow us to compute the sensitivity of the RAI to geometrical alterations in the bronchial tree. The effects of bronchoconstriction on the RAI may be evaluated quantitatively from measurement of increase in resonant frequency, decrease in reactance and modifications of the frequency-dependence of resistance. Moreover, the serial distribution of the airflow and pressure along the bronchial tree can be computed.

Further improvements in measuring techniques are still required. The *sensitivity* of the RAI to bronchial obstruction has been found to be excellent, but *specificity* for the nature and localization of the obstruction is lacking [4]. The study of the forward model suggests that the enlargement of the frequency range for the RAI evaluation should help to fill the gap.

A major difference exists between the experimental conditions in high frequency ventilation and those used for RAI measurements. RAI measurements are performed with minimal airflow amplitude, compatible with an acceptable signal to noise ratio. *High frequency ventilation* (HFV) in contrast, takes advantage of the use of turbulent and non-linear phenomena occurring at large airflows. The predictions concerning the serial airflows and pressures, which can be deduced from the RAI measurements, cannot be used without corrections for the choice of optimal parameters for HFV. However, we know from theory that the RMS values of the oscillating

airflows in each bronchial section play a major role in the diffusion of gases in HFV and optimization could be achieved if a good physical model of airflow could be obtained. We therefore suggest that forward models should be developed for RAI calculations in order to obtain more realistic values of airflow distribution at the various excitation frequencies.

It is probable that the RAI measurement may prove useful in adjusting ventilatory parameters and in monitoring the effectiveness of HFV. However, the technical aspects of monitoring are complex, and efforts are still being made to achieve a reliable monitoring of the RAI during HFV.

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