Clinical applications and modelling of forced oscillation mechanics of the respiratory system

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Over the past few years we have conducted a number of studies to assess the usefulness of the pseudorandom noise forced oscillation technique (FOT) [1], described by LÄNDSÉR et al. [2], and NAGELS et al. [3], for clinical practice. This technique consists of applying the complex signal at the mouth and recording of the resulting flow and pressure signal also at the mouth (input impedance). Changes in total respiratory resistance (Rrs) and reactance (Xrs), measured between 6–26 Hz, were investigated in the following disorders or conditions: a) upper airway obstruction [4]; b) asthma, chronic bronchitis and emphysema; c) bronchial challenge tests [5]; d) diffuse interstitial lung disease [6]; e) chest wall deformities (kyphoscoliosis and ankylosing spondylitis); and f) strapping of the thoracic cage [7], which can be considered as a physiological tool to mimic chest wall disorders.

Irrespective of the underlying disorder, changes in input impedance always presented the same characteristics, which consisted of an increase in Rrs, together with a decrease of Rrs with frequency and a decrease in Xrs with an increase of the resonant frequency. Differences in impedance data among the various obstructive and restrictive disorders were quantitative, not qualitative.

In airflow obstruction, i.e. upper airway obstruction, asthma, chronic bronchitis and emphysema, Rrs (and Xrs) were closely correlated with airway resistance (Raw). The changes in Rrs and Xrs were determined mainly by the degree of increase in Raw, whereas the site of this increase was of minor influence on the impedance curves. A model study indicated that this fact is connected with the important influence of the shunt properties of the upper airway wall on the values of Rrs and Xrs in obstructive patients. Concerning practice, in upper airway obstruction impedance is neither very sensitive nor able to assess the dynamic behaviour of the obstruction; in asthma, chronic bronchitis and emphysema input impedance can be used as an alternative for plethysmographic Raw and gives complementary information with respect to forced expiratory volume in one second (FEV1); for bronchial challenge tests in patients with normal baseline resistance FOT is more sensitive than the measurement of specific airway conductance (SGaw).

In the various restrictive disorders of the respiratory system the changes in Rrs and Xrs were proportional to the reduction in vital capacity (VC) and total lung capacity (TLC). For a similar reduction in TLC changes in Rrs and Xrs were more pronounced in kyphoscoliosis than in diffuse interstitial lung disease. In the former disease there is generally a substantial difference between Raw and Rrs. In diffuse interstitial lung disease a model study suggested in addition to the measured decrease in lung compliance and increase in lung tissue resistance, an increase in peripheral airway resistance and a decrease in lung compliance. In kyphoscoliosis and in ankylosing spondylitis a model simulation indicated that the changes in Rrs and Xrs were mainly attributable to an increase in chest resistance and to a decrease in chest wall compliance, while in kyphoscliosis changes in airway and lung mechanics were also produced. With respect to clinical practice we concluded that FOT can detect changes in chest wall mechanics, but the method lacks sensitivity. Finally the study on strapping of the thoracic cage demonstrated that partitioning of Rrs and Xrs into lung and chest wall components may be a more promising tool for the assessment of chest wall disorders.

References


Use of the forced oscillation technique in infants


Measurement of pulmonary function is difficult in infants. Since the forced oscillation technique (FOT) does not require co-operation, this method has the potential for providing useful pulmonary function data in this age group. The infant adapted Ländsér FOT, measuring resistance (Re) and reactance (Ra) of the respiratory system (RS) at frequencies between 4–52 Hz, rests on the assumption that the RS is linear for the amplitude of pressure applied, which implies that amplitudes of oscillating pressures and resulting flows are linearly related, reflecting a constant impedance.

The present study aimed at investigating the linearity of the RS in infants using FOT and assessing inter- and intra-individual reproducibility. To seven asthmatic infants, aged 1–22 mths, oscillations were applied at two amplitudes (1.8 and 2.4 cmH2O peak-to-peak). Mean Re measured at low and high amplitude was 0.1 cmH2O·L·s−1 (±7.8) and 0.0 cmH2O·L·s−1 (±3.4) at 48 Hz. Comparing higher pressure amplitudes (2.4 and 3.0 cmH2O) similar results were found. Differences were small with respect to the measured Re range and of no clinical relevance. The same applied for Ra. In 17 asthmatic infants, aged 1–22 mths, reproducibility was checked. At frequencies below 16 Hz, less accurate results were obtained with a higher coefficient of variation (CoV) due to poorer signal-to-noise ratio. The overall mean CoV at all frequencies was 6% and ranged between 12–4%. Overall mean relative error between two series of five measurements at a 15 min interval, assessing within-patient reproducibility, was 0.5±5.7%. In conclusion, constant impedance values with varying amplitudes of oscillations suggest that the RS of infants is linear up to resistances of 50 cmH2O·L·s−1. Inter- and intra-individual reproducibility was acceptable. This supports the validity of the use of this technique in infants.

Influence of obesity on lung volumes, respiratory resistance and reactance

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In 24 obese, nonsmoking women (mean age: 43 yrs; mean height: 1.60 m; mean weight: 88 kg; mean body mass index (BMI): 34.5 kg·m−2) we measured vital capacity, expiratory reserve volume (ERV) and forced expiratory volume in one second (FEV1) by means of a spirometer. Resistance (Rrs) and reactance (Xrs) of the respiratory system were determined between 2–26 Hz by means of a forced oscillation technique using a pseudorandom noise signal [1]. To estimate the distribution of the abdominal mass a computed tomogram was taken just above the iliac crest. The surface occupied by the intra-abdominal fat was related to that of the subcutaneous fat (IA/SC ratio). Among the lung volumes, only ERV (% predicted) was significantly correlated with IA/SC: an increase in IA/SC is accompanied with a decrease in ERV. No significant correlations were found between lung volumes and BMI. Total respiratory resistance (Rrs), although increased with respect to values determined in non-obese women, was not related to BMI. Similarly, no correlation was observed between BMI and Xrs. On the other hand, there was a significant positive correlation between mean Rrs (average from 8–26 Hz)