Plethysmographic assessment of airway resistance

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AIMS

- Physiology of Airflow Resistance
- How we measure airflow resistance using Whole Body Plethysmography
- Plethysmographic Specific Airway Resistance
  - Principles
  - Clinical applications: Methodological differences
  - Future directions

SUMMARY

Lung function techniques that can be applied during tidal breathing are particularly pertinent in young children where active cooperation and understanding may be reduced, and adults with severe lung disease in whom, active manoeuvres may be challenging. Plethysmographic Specific Airways Resistance (sR_{aw}) is measured during tidal breathing when the relationship between simultaneous measurements of airflow and the change in plethysmographic pressure is assessed without the need for any special breathing manoeuvres against an airway occlusion.[1] sR_{aw} is the product of Functional Residual Capacity (FRC) and Airways Resistance (R_{aw}) and can be calculated from the relationship of plethysmographic box pressure (P_{box}) to flow during spontaneous breathing. Derivation of sR_{aw} occurs as follows:

1) $\mathbf{R_{aw}} = (\Delta V_{box\_spontaneous} / \Delta flow) / (\Delta V_{box\_occlusion} / \Delta P_{mouth})$
2) FRC = $(\Delta V_{box\_occlusion} / \Delta P_{mouth}) \times (P_{amb} - P_{H2O})$

Where
$\Delta V_{box\_spontaneous}$ = change in box volume during spontaneous breathing
$\Delta V_{box\_occlusion}$ = change in box volume during efforts against the airway occlusion (shutter)
ΔP_{mouth} = change in mouth (alveolar) pressure during efforts against the airway occlusion
P_{amb} = ambient pressure
P_{H2O} = water vapour pressure

Equations (1) and (2) are then combined:

3) $$\mathbf{sR_{aw}} = \frac{\Delta V_{box\_spontaneous} / \Delta flow}{\Delta V_{box\_occlusion} / \Delta P_{mouth}} \cdot \frac{\Delta V_{box\_occlusion}}{\Delta P_{mouth}} \cdot (P_{amb}-P_{H2O})$$

And simplified, thereby avoiding need for an airway occlusion with which to calibrate box pressure changes in terms of alveolar pressure changes.

4) $$\mathbf{sR_{aw}} = \Delta V_{box\_spontaneous} / \Delta flow \cdot (P_{amb}-P_{H2O})$$

Thus, in the simplest form, sR_{aw} can be derived from the tangent of the slope of box Pressure/Flow. Since R_{aw} has a strong inverse relationship to lung volume, sR_{aw} provides a relatively stable index with which to distinguish effects of disease from those of growth and development. [1,2] sR_{aw} is significantly increased compared to healthy children in groups of asthmatic children, [3-7] those with wheezing disorders, [8] and cystic fibrosis.[9] It has also been shown to be a useful outcome measure

for bronchodilator responsiveness studies. [6] Clinical applications, however have been limited due to a lack of consensus with regards to equipment, measurement conditions, data collection, analytical strategies and reference data.[10] In 2010, the asthma UK initiative highlighted methodological differences, and developed reference data which could be used under specific conditions.[11] Since this publication, an international collaboration have formed and are working towards standardising the measurement.[12]

Much emphasis has been placed on standardising methodology equipment differences. Each manufacturer has produced different software, and the relationship between plethysmographic (box) pressure and airflow can be analysed in a variety of ways. With the exception of 'effective resistance' (sR_{eff}), which was calculated as a regression of pressure and flow over the entire breathing cycle (with each manufacturer potentially producing its own specific algorithm for this calculation), the sR_{aw} outcome is generally derived from the tangent of the slope of P/F which can be placed:

- between peak inspiratory and peak expiratory flow (sR_{peak}).
- between points of maximum plethysmographic (box) pressure (total resistance, or sR_{tot})
- over some fixed range of flow, over the central linear portion of the breath (most frequently between 0-0.5 $L.s^{-1}$ i.e. $sR_{0.5}$)

While computation over a limited flow interval is recommended in adults,[13] application of the fixed flow range in children should be used with caution since it is likely to provide age dependent estimates of sRaw with more significant non linearity's in smaller than in taller children. $sRaw_{0.5}$ has however, been shown to be discriminative asthmatic children from controls in a limited age range,[14] and will be considered further as reference data is developed. Further areas for development are the use of different flows attained, and the thermal adjustment applied.[14]

In conclusion, despite some limitations with regards to standardized methodologies, sRaw has been shown to discriminate health and disease and is a useful outcome measure in subjects in whom forced maneuvers may prove difficult. The user should ensure interpretation of sRaw results is performed with appropriate reference data that is applicable to the population, equipment and measurement protocols they are applying.

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