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Body plethysmography (I): Standardisation and quality criteria☆

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Abstract Whole body plethysmography is used to measure lung volumes, capacities and resistances. It is a well standardised technique, and although it is widely used in paediatric chest diseases units, it requires specific equipment, specialist staff, and some cooperation by the patient. Plethysmography uses Boyle's law in order to measure the intrathoracic gas volume or functional residual capacity, and once this is determined, the residual volume and total lung capacity are extrapolated. The measurement of total lung capacity is necessary for the diagnosis of restrictive diseases. Airway resistance is a measurement of obstruction, with the total resistance being able to be measured, which includes chest wall, lung tissue and airway resistance, as well as the specific airway resistance, which is a more stable parameter that is determined by multiplying the measured values of airway resistance and functional residual capacity. The complexity of this technique, the reference equations, the differences in the equipment and their variability, and the conditions in which it is performed, has led to the need for its standardisation. Throughout this article, the practical aspects of plethysmography are analysed, specifying recommendations for performing it, its systematic calibration and the calculations that must be made, as well as the interpretation of the results obtained. The aim of this article is to provide a better understanding of the principles of whole body plethysmography with the

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aim of optimising the interpretation of the results, leading to improved management of the patient, as well as a consensus among the speciality.

PALABRAS CLAVE
Pletismografía corporal total;
Volumen de gas intratorácico;
Capacidad residual funcional;
Resistencia total de la vía aérea;
Resistencia específica de la vía aérea

Pletismografía corporal (I): estandarización y criterios de calidad

Resumen La pletismografía corporal completa permite la medición de volúmenes, capacidades y resistencias pulmonares. Es una técnica bien estandarizada y ampliamente utilizada en neumología pediátrica, aunque requiere equipo específico, personal especializado y cierta colaboración por parte del paciente. La pletismografía utiliza la ley de Boyle para determinar el volumen de gas intratorácico o capacidad residual funcional, y una vez determinada esta, se extrapolan el volumen residual y la capacidad pulmonar total. La medición de la capacidad pulmonar total es necesaria para el diagnóstico de patología restrictiva. La resistencia de la vía aérea es una medida de obstrucción, pudiéndose determinar la resistencia total, que incluye la resistencia de la pared torácica, tejido pulmonar y vía aérea, y la resistencia específica, que es un parámetro más estable que corresponde al producto de la resistencia de la vía aérea por la capacidad residual funcional. La complejidad de esta técnica, las ecuaciones de referencia, las diferencias en el equipamiento, la variabilidad de la misma y las condiciones en las que se realiza han hecho necesaria su estandarización. Se analizan a lo largo del artículo los aspectos prácticos de esta técnica, especificando las recomendaciones para su realización, sistemática de calibración y los cálculos que se deben llevar a cabo, así como la interpretación de los resultados obtenidos. El objetivo de esta publicación es favorecer una mejor comprensión de los principios de la pletismografía completa con el fin de optimizar la interpretación de los resultados favoreciendo un mejor manejo del paciente y un consenso en la especialidad.

Measurement of static lung volumes. Body plethysmography

Introduction

In 1956, Dubois et al. described whole-body plethysmography based on Boyle's law, according to which the volume (V) of a gas at a constant temperature varies in inverse proportion to the pressure (P) to which it is subjected, with $P \times V$ remaining constant.[1,2]

While spirometry[3] is the most commonly used method to assess lung function in clinical practice, at times it is necessary to measure the volume of the air that the lungs cannot displace (static lung volumes). Thus, plethysmography remains an essential technique in the assessment of lung function. It measures several gas volumes, such as the intrathoracic gas volume (TGV) or the functional residual capacity (FRC), the residual volume (RV) and the total lung capacity (TLC).[4,5] The addition of two or more lung volumes makes up a lung capacity (Table 1). This technique also measures total airway resistance (RawTOT), specific airway resistance (sRaw), airway conductance (Gaw) and specific airway conductance (sGaw).

Unlike other techniques like nitrogen washout or helium dilution that underestimate the FRC because they do not measure poorly ventilated or unventilated spaces (bullae), plethysmography measures the full volume of intrathoracic gas.

There are three kinds of plethysmographs, and the one used most commonly is the constant-volume plethysmograph.[4]

Equipment

It must include:

- Airtight chamber (2 models: older children/adults; infants).
- Pneumotachograph. It must meet the standards for spirometric devices (ATS/ERS 2005[6]): capable of measuring volumes of 0.5–8.00 L with an accuracy of ±3% as calibrated with a 3.00 L syringe, flows between 0 and 14 L/s, and recording durations of at least 30 s.
- Shutter valve and pressure transducer to measure pressure changes at the mouth. The pressure transducer must have a sensitivity greater than 50 cm H_2O and a flat frequency response in excess of 8 Hz. This depends on the breathing frequency during the TGV manoeuvre, which should not be greater than 1.5 Hz.
- Pressure transducer inside the plethysmograph chamber (constant-volume variable-pressure plethysmographs). It measures the pressure within the chamber. In some systems another pneumotachograph is placed on the plethysmograph wall to measure volume changes inside the chamber (constant-pressure variable-volume plethysmographs). It must be accurate to ±0.2 cm H_2O.