Chapter 9 - Whole Body Plethysmography

9.1 Introduction

Menzies described whole body plethysmography in 1796 when he plunged a man into a barrel containing water and measured the rise and fall of the level during the breathing cycle. He used this method to determine tidal volume. The technique for measuring airway resistance was first described by DuBois in 1956 [1,2]. The first whole body plethysmograph to be made commercially was manufactured in 1969.

The main function of the modern plethysmograph is to allow the measurement of Thoracic Gas Volume (TGV), Functional Residual Capacity (FRC), lung volume subdivisions, airway resistance (Raw), specific airway resistance (SRaw), conductance (Gaw) and specific conductance (sGaw). Most modern commercial systems also have other options available to measure respiratory parameters such as conventional and compression-free flow volume loops, transfer factor, maximal mouth pressure and lung compliance.

Measurement of FRC by helium dilution and nitrogen washout may be underestimated in obstructive lung disease due to poor gas mixing within the airways and thoracic cavity. PlethysmographyFu will measure all thoracic gas, including that which may be trapped in poorly ventilated areas. The difference in volume measured by the methods may be used as an index of gas trapping.

Measurements of Raw, SRaw, Gaw and sGaw are not dependent on effort and may be used to assess airflow obstruction in those subjects who are unable or unwilling to perform forced manoeuvres, such as the measurement of FEV_1. It is possible to make the measurement of SRaw in children as young as three years old [3,4]. The measurement of SRaw is described in Chapter 9, ARTP 2003.

Raw, Gaw and SGaw measurements may be used in place of FEV_1 when performing bronchial challenge testing.

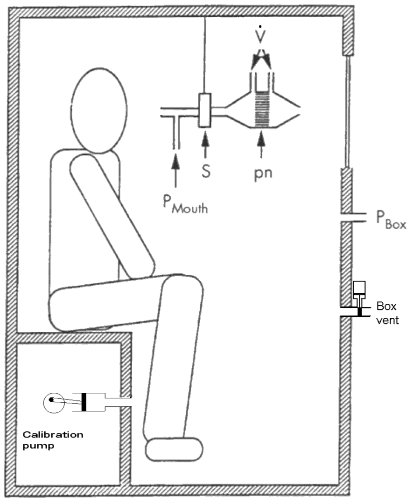
9.1.1 Types of Plethysmograph

There are typically two types of plethysmograph which are commercially available: the constant volume, variable pressure plethysmograph and the constant pressure, variable flow plethysmograph. Some manufacturers combine both options in one machine. The most common machine in use is the constant volume, variable pressure plethysmograph. Other types of volume displacement plethysmograph have been developed which utilise a spirometer to measure volume changes within the plethysmograph.

9.1.1.1 Constant Volume / Variable Pressure Plethysmograph

The subject is completely enclosed and breathes from within the plethysmograph. Mouth pressure (P_{mouth}) and plethysmograph pressure (P_{Box}) are measured by individual transducers. The mouthpiece is attached to a shutter assembly (S) and a pneumotachograph (pn) across which flow ($\dot{V}$) is measured. Usually airflow at the mouthpiece is integrated to give volume. By utilising Boyle's law, it is possible to measure volume changes within the plethysmograph by measuring the change of pressure within the plethysmograph, providing temperature remains constant and a calibration factor has been determined. The magnitude of volume change during the measurement procedure is often very small (typically 150 ml or less) therefore the plethysmograph pressure transducer must be extremely sensitive. Pressure plethysmographs should be sited away from opening doors, windows, radiators and draughts to prevent localised temperature and pressure changes affecting the measurements. Creating a small leak within the plethysmograph to allow excess pressure to be dissipated will compensate for pressure changes within the plethysmograph caused by body temperature.

Figure 9.1 Constant volume, variable pressure plethysmograph where: P_{mouth} = mouth pressure transducer, pn = pneumotachograph, S = shutter assembly and P_{box} = plethysmograph pressure transducer



9.1.1.2 Constant Pressure / Variable Flow Plethysmograph

This is similar in design to the constant volume, variable pressure plethysmograph with the exception that a flow transducer replaces the plethysmograph pressure transducer [5]. Volume changes within the plethysmograph are measured by integrating the flow signal. Flow, volume and pressure signals must be processed in phase during the measurement which requires the use of a computer. Pressure drift due to thermal changes must again be allowed for, however these are less significant than in the constant volume, variable pressure plethysmograph.

Figure 9.2 Constant pressure, variable flow plethysmograph