3.3 Lung Function for Radiology

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CONTENTS

3.3.1 Introduction 101
3.3.2 Lung Volumes 101
3.3.3 Divisions of the Total Lung Capacity 102
3.3.4 Workers with Small Lungs 102
3.3.5 Measurement of the Transfer Factor (DLCO) and Transfer Coefficient (KCO) 103
3.3.6 Workers with Large Lungs 105
3.3.6.1 Measures of Forced Expiration and Inspiration 106
3.3.6.2 Asthma 109
3.3.7 Specific Bronchial Provocation Testing 112
3.3.7.1 What is Normal Lung Function? 112
3.3.7.2 Monitoring of Disease Progress 112
3.3.8 References 113

3.3.2 Lung Volumes

The total lung capacity is the volume of air within the lungs at full inspiration. It is commonly estimated from the chest X-ray or computed tomography (CT) scan and can be formerly calculated radiographically, provided that care is taken to acquire the images truly at full inspiration (Clausen 1997). Taking a truly full inspiration is uncomfortable and takes longer than is often allowed in conventional radiological practice. It is also reduced in the supine position. Radiologically derived total lung capacity includes the air within the lungs, the intrapulmonary interstitial tissue and the intrapulmonary blood volume.

Lung function laboratories can measure total lung capacity by body plethysmography or inert gas dilution. The standard body plethysmograph is a sealed cabinet of constant volume. The subject sits inside, breathing through a mouthpiece that measures volume and pressure at the mouth. As the subject breathes in and out, the volume changes. As the cabinet is of fixed volume, the pressure of the air within the cabinet changes slightly. During the manoeuvre, a shutter obstructs the movement of air during an attempt at inspiration and expiration. The changes in pressure within the mouthpiece and the cabinet are measured; as the volume within the plethysmograph is constant, the volume of gas compressed within the subject can be calculated (by Boyle’s law, where pressure x volume is a constant). This method measures compressible gas volume. It would include air in non-communicating bullae, pneumothorax spaces, the oesophagus and some air within the stomach. It excludes the blood and interstitial volumes included radiographically. The measurement is accurate in those with low and normal lung volumes but can overestimate volume in those with significant airflow obstruction, as the mouth pressure measured may not be the same as the intra-alveolar pressure.

Gas dilution lung volumes are usually measured with helium. The subject is connected to a closed
circuit system where the carbon dioxide is absorbed and oxygen replenished. Helium is normally neither secreted nor absorbed. The test continues until the expired helium concentration plateaus, as the inspired helium is diluted by the air within the lung at the time of connection. In normal subjects, this takes a few minutes, but in patients with significant emphysema, equilibrium may not be achieved for 10–20 min. Stopping before a steady state is reached is common in patients with severe emphysema. The Helium dilution lung volume measures air accessible to the mouth, excluding gas within the gastrointestinal tract, pneumothorax spaces or in non-communicating bullae, and, in a normal adult, is approximately 500 ml less than the volume measured by body plethysmography. The helium lung volume can also be measured with a single breath hold, where it is called the alveolar volume. This is a routine part of the gas-transfer measurement, where a 10-s breath hold is used. The lung volume accessible to helium in this time excludes poorly ventilated areas but is a measure of the volume of air that can be accessed by the subject during normal activities. The difference between the alveolar volume and the total lung capacity is a measure of trapped air, seen radiologically as the darker component of the mosaic pattern seen in patients with small airways disease.

3.3.3 Divisions of the Total Lung Capacity

After a full expiration, there is air left within the lungs; this is the residual volume and cannot be measured directly. It is calculated by measuring the total lung capacity and subtracting the vital capacity. The vital capacity (or forced vital capacity if the subject is asked to breathe out as hard and fast as possible) is measured directly by asking the subject to inhale until no more air can be inhaled and then breathe out until flow ceases.

The total lung capacity is reduced when the lungs are small, as in asbestosis, when the lungs are restricted by pleural effusion or thickening, or when the chest wall restricts lung expansion, as in obesity. It can also result from diaphragm palsy or compression by abdominal contents, such as in pregnancy or with ascites. The total lung capacity is increased when there is obstruction to airflow during exhalation, particularly in emphysema, where the obstruction is due to collapsing airways, and more severe asthma, where it is due to bronchial inflammation and narrowing.

3.3.4 Workers with Small Lungs

Figure 3.3.1 shows the total lung capacity, which is the sum of the vital capacity and the residual volume, expressed as a percentage of the expected normal value, for two workers with small lungs.

Worker 1 is an 82-year-old man who was a stoker in the engine room of an aircraft carrier between 1942 and 1947. He then became a school caretaker between 1947 and 1987, where he had to look after the boilers, which were initially coke fired and later converted to burn oil. He developed left-sided chest pain and breathlessness. Examination showed late inspiratory crackles at both bases and reduced movement and dull percussion on the left.

Worker 2 is a 55-year-old man who, for the past 11 years, serviced fork-lift trucks in a factory manufacturing car engines with incidental exposure to aerosols of metal-working fluid. He had been breathless for 6 months and lost 4 kg in weight but had improved considerably when off sick in the 3 months prior to being seen. Examination showed late inspiratory crackles at both lung bases.

![Graph of Vital capacity and Residual Volume](image-url)