Introduction

The assessment of regional lung ventilation and perfusion of the lung is of importance in the diagnosis of pulmonary emboli, in the functional evaluation prior to lung resection, in grading functional impairment in chronic obstructive and restrictive lung disease, mucociliary dysfunction and in experimental and clinical research. With and increasing knowledge of the non-uniform distribution of ventilation and perfusion, and of other morphological and functional variables, assessment of regional lung function is becoming increasingly important. This paper will offer a short historical background, analyze methodological problems of advanced gamma camera technique, and present data for anaesthetized humans.

Historical Background

In 1955 Knipping et al. used for the first time radioactive gas (volatile methyl iodide labelled with iodine-131) for the study of regional ventilation and blood flow [1]. Radioactivity in various parts of the lung was measured with external counters. Using this study, they could detect regional differences in ventilation caused by local disease. West and Dollery [2] demonstrated regional differences in blood flow using oxygen-15, a short-lived cyclotron-produced isotope. This isotope is inhaled in the form of carbon dioxide and the rate at which it is removed from a region of the lung during breath-holding is a measure of local blood flow. Ball et al. [3] showed that blood flow as well as ventilation could be measured using reactor-produced xenon-133. The use of more long-lived radioactive substances made the isotope technique generally available.

Taplin et al. [4] introduced radioactive macroaggregates for the assessment of the distribution of lung blood flow. Initially, measurements were made of albumin labelled with iodine-131, but technetium-99m is superior because of its shorter half life and lower energy, which provides a better counting efficiency. Regional ventilation was assessed by inhalation of radioactive gas, xenon-133, or later on, krypton-85. The latter isotope has a more suitable energy level but its short half-life (13 s) requires its production on-site by means of a rubidium generator [5]. During the seventies, the inhalation of isotope-labelled particles and recording of their deposition in the bronchial tree were increasingly used for the study of ventilation distribution [6, 7].
The imaging of isotope activity within the lung has also undergone considerable development. In the very first method of measuring regional ventilation, 16 counters were positioned over the posterior aspects of the chest [8]; much fewer counters have been used in most later studies. An alternative solution is to move pairs of counters over each lung (scanning technique) [9]. This requires very stable conditions and precludes an analysis of dynamic events. In most laboratories these techniques have been replaced by the gamma camera, a large sodium iodide crystal, in which gamma rays are focused by a series of parallel holes in a lead collimator [10]. By arranging series of photomultipliers behind the crystal, the position and intensity of the scintillations can be shown as a two-dimensional display.

A three-dimensional distribution of the isotope activity, or a two-dimensional display perpendicular to the gamma camera, can be reconstructed by counting the activity while the gamma camera is moving around the body (the camera stops briefly at different angles for the measurement of activities). Since the gamma rays are emitted as single photons, the technique is called single photon emission computed tomography (SPECT).

Nuclides, which emit positrons are the basis for another technique, coincidence counting. When the positron collides with an electron, two gamma rays are given off in exactly opposite directions. If the thorax is surrounded by a ring of many small crystals, the simultaneous detection of the two gamma rays gives positional information. This technique, positron emission tomography (PET) enables the same spatial imaging as SPECT, but has the advantage of permitting detection of fast events, whereas SPECT only allows an analysis of static situations (or the "freezing" of a dynamic event). The PET-technique is, however, hampered by the need for large heavy equipment and cyclotron-generated short-lived isotopes [11, 12].

**Present Research Situation**

Since a progressively greater, top-to-bottom, pulmonary ventilation and blood flow have been demonstrated, the clinical use of the gamma camera has been confined mainly to the detection of pulmonary emboli by obtaining two-dimensional views of the lungs. Not until recently has a new interest emerged: the analysis of regional ventilation and blood flow. This is due to accumulated evidence suggesting a non-uniform and non-gravitational distribution of ventilation and blood flow, i.e. in the medial–lateral and cranial–caudal directions in a supine subject. A non-gravitational non-homogeneity of the perfusion distribution was suggested by some studies during the seventies in anaesthetized dogs. Thus there was more perfusion in the middle of the lung and less in the periphery during conventional mechanical ventilation [13], and a redistribution of blood flow towards the lateral and basal borders during ventilation with positive end-expiratory pressure (PEEP) with the animal in supine position [14]. After ventilation with gas containing radioactively labelled microspheres, the lung was removed, cut into small pieces and the activity was measured. Distortion of the lung from its in vivo shape could therefore not be ruled out. Recent reports on studies of the perfusion distribution in awake healthy