DEPOSITION AND SHORT-TERM CLEARANCE OF AEROSOL PARTICLES IN THE HUMAN RESPIRATORY TRACT

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INTRODUCTION

Health effects resulting from particle inhalation are related to the sites of deposition in the respiratory tract and the pattern of clearance from each site. When particles are inhaled, two distinct phases of clearance from the thorax are usually observed. It is generally assumed that the fast phase, which is complete within about a day, represents mucociliary clearance of particles deposited in the tracheobronchial tree, and the slow phase represents clearance of the alveolar deposit. This assumption forms the basis of measurements of regional deposition using radioactively labelled aerosols. To investigate these assumptions, lung clearance experiments are being conducted in which particles labelled with gamma emitting radionuclides are administered as "bolus" of aerosol, injected at a predetermined point in the breathing cycle, to restrict particle deposition to a relatively small region of the lung.

MATERIAL AND METHODS

With an inhalation technique described in a previous paper it is possible to inject aerosol boluses with defined volumes at any moment during inhalation into the inspired air (1). For technical reasons the method was optimized using pulses of about 50 cm$^3$ volume. By varying the point of injection during inspiration and by holding the breath at end-inhalation deposition of particles in different volumetric lung depths was achieved. Other parameters which have been controlled were the particle size and the respiratory flow rate. By this way it was expected that particle clearance can be measured as function of the site of particle deposition in the lung. Monodisperse spherical iron oxide particles between 1.2 to 3.5 μm aerodynamic diameter were produced by atomization of an aqueous colloidal solution of Fe$_2$O$_3$ with a spinning top generator. For radioactively labelling the Fe$_2$O$_3$-colloid was mixed with colloidal $^{198}$Au.

Four male nonsmokers with normal lung functions volunteered in the experiments. Starting from ERV, variable volumes of more than 900 cm$^3$ of clean air were inhaled at a constant flow rate of 250 cm$^3$. At this level a 50 cm$^3$-bolus containing radioactively labelled particles was injected by means of a valve system and inspiration of clean air was continued until a fixed tidal volume of 1000 cm$^3$ was completed. Some experimental parameters used in the aerosol pulse technique are defined in accordance with Fig. 1 as follows: The front depth of a pulse is the volumetric distance between larynx (1) and the front of the pulse at end-inspiration under the assumption that the pulse is not affected by convective inspiraction (dispersion) after it has passed the photometer. The penetration of a pulse is the volumetric distance between the entrance of the mouth (M) and the mode (concentration maximum) of the bolus at end-inspiration.
Since the oral cavity represents a large dead space which would cause convective mixing during inhalation it was bridged over by a tube and the cavity outside the tube was filled with a preformed material. So the dead space was reduced to the volume of the tube, pharynx, and larynx. In the example in Fig. 1, the front depth is 80 cm$^3$, and the penetration 68 cm$^3$. These values are based on the assumption that the dead space between mouth entrance (M) and larynx (L) was 15 cm$^3$; this is assumed to be a minimum value, so that for larger dead spaces the front depth becomes even smaller.

The retention measurement of the deposited particles was started immediately after the bolus inhalation.

RESULTS

To bring more light into the results obtained in previous investigations, experiments were carried out where the size of the inhaled particles and the period of breath-holding were varied in such a way that the settling distance of the particles during the inspiratory pause remained constant. In other words, when the particle diameter, $d_{ae}$, was increased by a factor of 2, the time of breath-holding was decreased by a factor of 4, so that the sedimentation parameter $d_{ae} t_p$ was the same. This procedure was to ensure that at a preset front depth deposition took place in the some volumetric lung depth regardless of the particle size. As a consequence of their equal deposition pattern, these particles should be also cleared in the same manner.

As one can see from Fig. 2, however, clearance was found to depend on particle size in such a way that a greater fraction of the larger particles was cleared in the fast phase, suggesting a smaller deposition in nonciliated airways and a larger deposition in ciliated airways as compared to smaller particles.