Editorial

Importance of airway geometry and respiratory parameters variability for particle deposition in the human respiratory tract

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The quantitative estimation of particle deposition in the respiratory tract is the important practical step for prediction of potential health outcome of inhaled aerosols. Such knowledge is indispensable in assessing aerosol toxicology as well as in the optimization of the drug delivery to the lungs by inhalation (1-3).

This problem is complex since many factors simultaneously play a role in this process, resulting in a high variability of regional and total deposition efficiency. These most important factors can be listed as follows:

a) the respiratory tract geometry, which is highly variable with age or body size and health conditions
b) the breathing pattern, which depends on the age and health, but also on the momentary physical activity
c) aerosol properties (particle size, shape, density, hygroscopity, surface properties, etc).

Aerosol particles, depending on their size and mass, can be deposited in different parts of the respiratory system due to action of several physical mechanisms, where the inertial impaction, gravitational settling and Brownian diffusion are the predominant ones.

Several approaches are used to estimate quantitatively the aerosol deposition fractions in different regions of the respiratory tract. The recent concepts - which are still under development - employ the Computational Fluid Dynamics (CFD) to identify the air flow pattern and motion of aerosol particles in the human respiratory system (4). This technique is demanding both from conceptual and computer-power viewpoints. Providing that the regional geometry of the air passages can be implemented correctly in form of the numerical mesh, CFD allows for a very detailed flow analysis of inhaled aerosol particles in the network of the real airways. Any type of physiological situation can be potentially modeled with this computational approach, including diseased lungs, pediatric patients, etc. Anyway, the methodology is not straightforward and quite often simplifying assumptions are introduced into the models to obtain the results in the reasonable computational time and accuracy. For instance, CFD simulations for the respiratory system are typically simplified by assuming constant airflow rates (5-9), although such presumption is far from the reality. Recently, the more accurate simulations for the unsteady airflow patterns (i.e. the real-like breathing curves) has become available (10-12).

No potential conflict of interest.

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Another method used for the estimation of aerosol deposition in the human respiratory system employs semi-empirical models which were developed taking into account the averaged deposition data obtained in vivo and in vitro (13-15). In this method the information on the deposition in the whole lungs as well as in the selected regions of the respiratory system can be analyzed. The advantage of such approach is its mathematical lucidity, although the proposed equations certainly are lacking the universality as they do not address many of the significant factors indicated earlier.

In any method of quantitative prediction of aerosol deposition the important problem is their validation due to the large scatter of in vivo data (variability) observed among different subjects (16). In this issue of the Journal of Thoracic Disease, Hussain et al. discuss the problem of variability in the estimated regional deposition fractions of inhaled aerosol particles, which is caused by intersubject differences of extrathoracic (ET) dimensions and breathing patterns (17). The authors use selected models (13,14,19,20) to calculate the deposition efficiency in nasal and oral regions for variable airways dimensions taken from the literature (21,22), and then combine these results with the stochastic IDEAL model (23,24) which allows to determine the deposition fractions in each generation of the tracheobronchial tree. In effect, the authors are able to demonstrate that variability in ET geometry have a noticeable influence on the total and regional deposition fraction, both for oral and nasal breathing. Obviously, such deposition data are dependent on breathing regime, what is also demonstrated in the paper (breathing at rest vs. light exercise). Based on their computational results, the authors show that intersubject variability of the ET geometry is an important factor for the regional and total aerosol particle deposition in the respiratory tract. It is also concluded that some more general metrics of ET anatomy (e.g., the scaling factor: SF) can be appropriate for description of the intersubject deposition variability.

This interesting paper does not cover of course the full complexity of the problem which was stated in the beginning of this editorial. However, the presented results - according to the authors' conclusion - may serve as a baseline to analyze more complicated cases in the future, e.g., for the lung pathology, when the intersubject deposition variability is expected to be much higher (the reasons for that are the different regional geometry of diseased lungs due to airways obstructions and highly variable airflow patterns - for some recent data on that issue see for example (25).

Readers of the paper by Hussain et al. will also take an additional advantage from the comprehensive presentation of the most common semi-empirical computational models that can be used for the estimation of aerosol deposition in the human respiratory system. This undoubtly helps to recognize the importance of different physical mechanisms in the deposition of inhaled aerosol particles with different sizes, but also – of the parametric sensitivity of the process under consideration. The awareness in this aspect seems to be essential in the designing the effective therapy of lung diseases by inhalation of aerosolized medicines.

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