Effect of Carrier Gas Properties on Aerosol Distribution in a CT-based Human Airway Numerical Model

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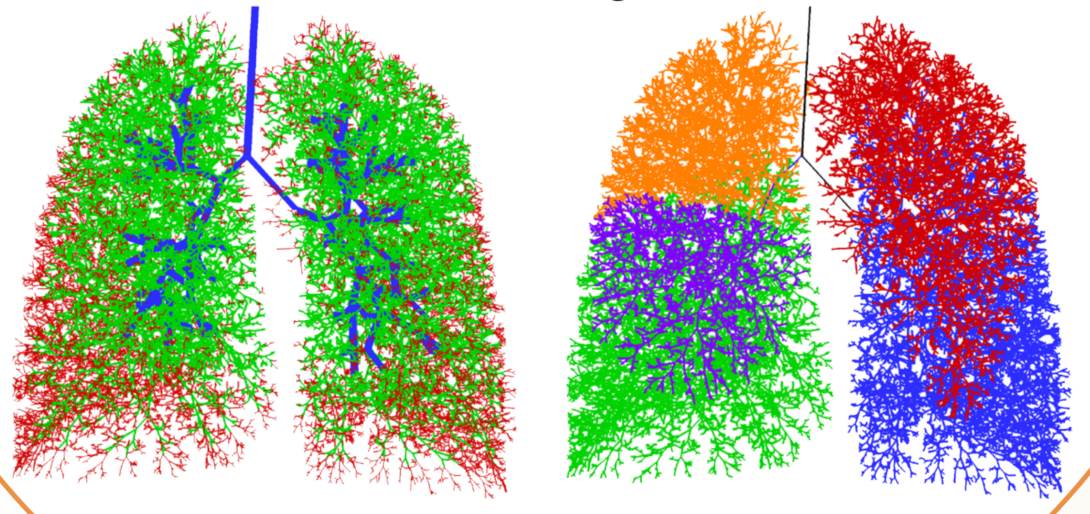
1. Effective Drug Delivery

The mechanisms of regional aerosol distribution are investigated to maximize therapeutic drug effect, minimize unwanted side effects, and reduce treatment cost by effective delivery of inhaled drugs to different regions of interest in the lung.



Serial targeting   Parallel targeting

2. Unsteady Simulation

In turbulent flows ($Re_{trachea}$ > 400~600)
(Time-averaged flow + α + particle)
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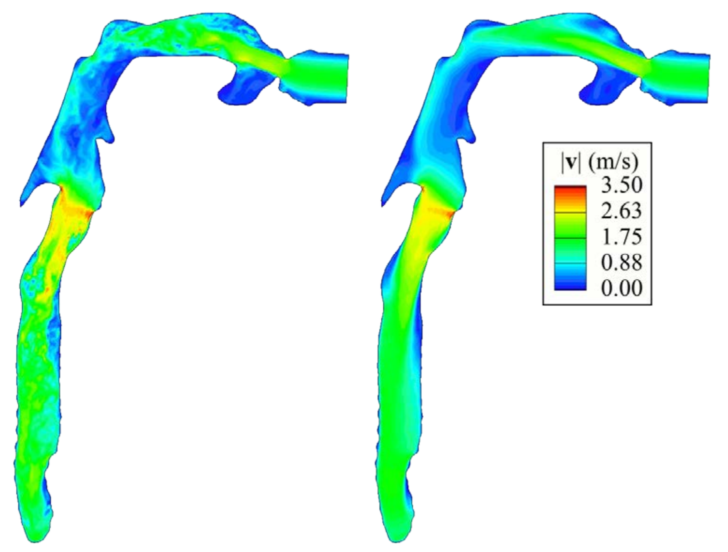
Time-averaged (flow + particle)

- Non-linear nature of fluid and particle motion
- Different temporal and spatial scales of turbulent flow structures

Instantaneous flow field
- anisotropic turbulence
- oscillation of jets



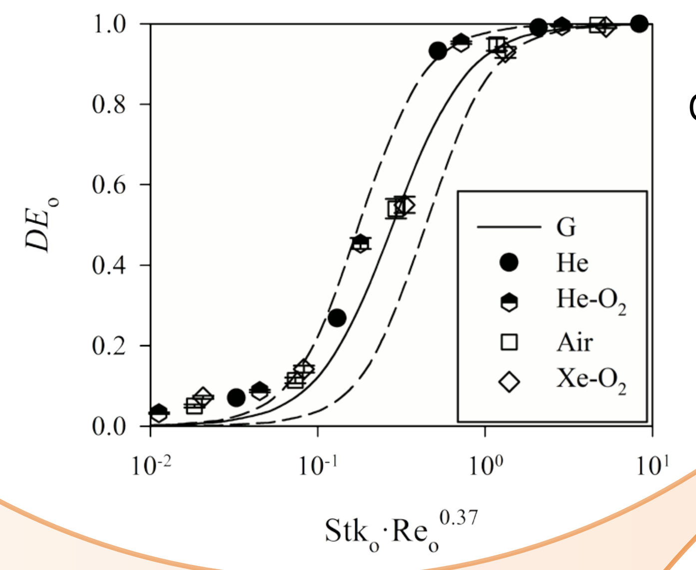
Time-averaged flow field + α
- isotropic turbulence
- steady jets

3. Numerical Simulation

Gas flow simulation (CFD)
- Large eddy simulation (LES) (3-D, unsteady, eddy-resolving)
- Gas property: He, He-O_2, air, Xe-O_2
- Steady inspiratory flow: 342 mL/s

Aerosol simulation (Lagrangian particle tracking)
- Unsteady flow field for turbulent flow
- Particle size = 2.5 μm

DE_o, Stk_o, Re_o = deposition efficiency, *Stk*, and *Re* for oral cavity



G = Grgic et al. (2004)

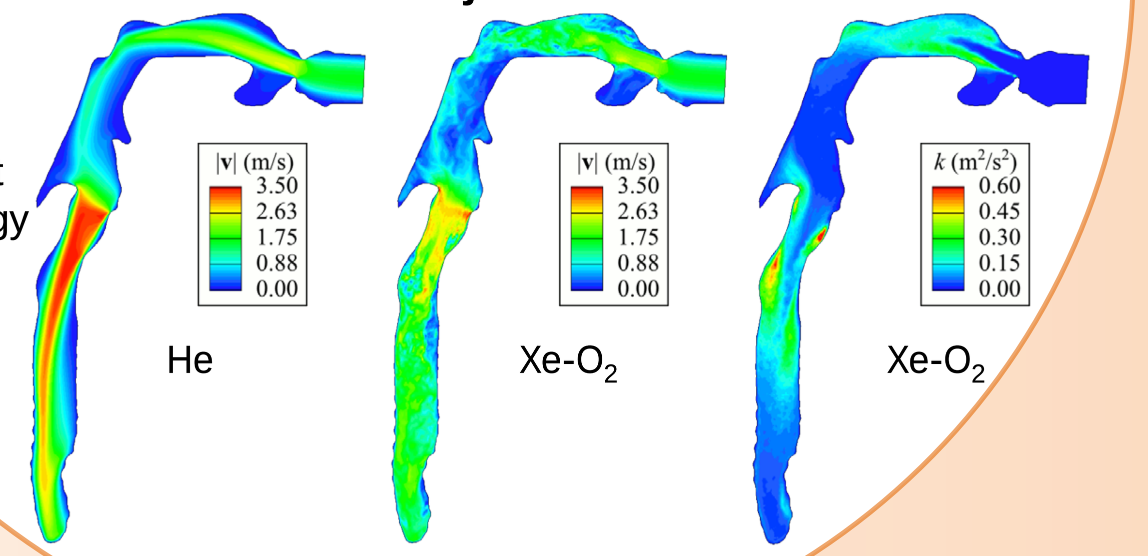
4. Laminar and Turbulent Flows

He (Re_t ~ 190): Laminar flow, flow field does not vary in time (stable).

He-O_2 (Re_t ~ 460): Transitional flow, low-frequency oscillation of jets in the oral cavity and trachea. Critical Re_t ~ 430.

Air, **Xe-O_2** (Re_t ~ 1300, 2800): Turbulent flow, dispersed flow and shorter jets.

v = velocity
k = turbulent kinetic energy



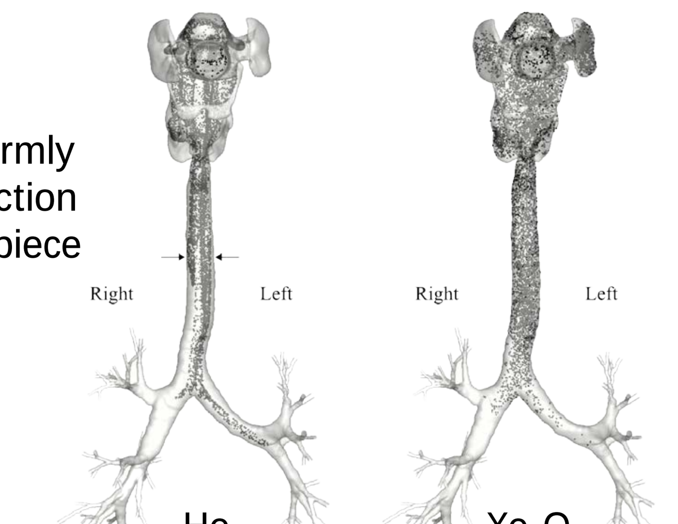
5. Aerosol Distribution

He: Small particles basically follow the steady streamlines of the flow, so the particles are not well mixed.

He-O_2: Particles are mixed by the jets oscillating with low-frequency in the oral cavity and trachea.

Air, **Xe-O_2**: Particles are well mixed by the turbulence in the oral cavity and trachea.

The aerosols are distributed uniformly in the cross-section at the mouthpiece



He (0.195 s)   Xe-O_2 (0.228 s)

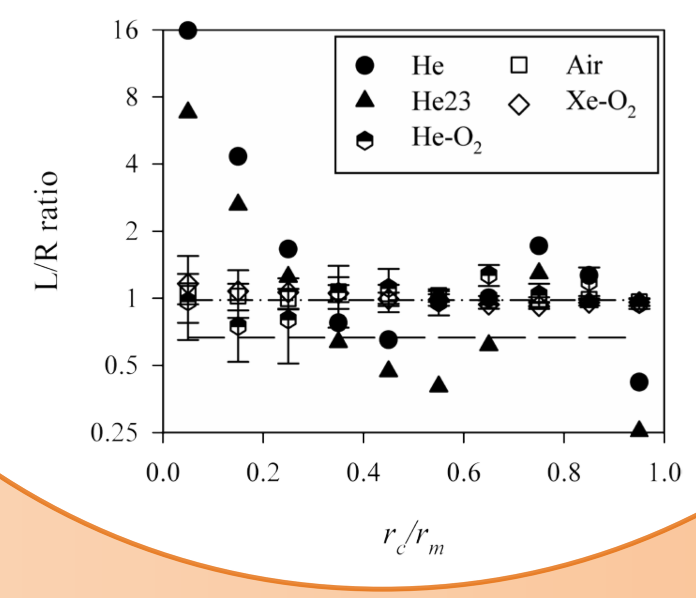
6. Parallel Targeting

He: L/R particle distribution of small particles depends on the particle location at the mouthpiece. Large deviation of L/R particle distribution ratio from the L/R ventilation ratio.

He-O_2: Large uncertainty due to the low-frequency oscillation of the jets.

Air, **Xe-O_2**: L/R particle distribution of small particles depends on the L/R ventilation ratio.

L/R ratio = L/R particle distribution ratio



r_m = radius of mouthpiece
r_c = radial coordinate of particles at mouthpiece

7. Conclusions

The regional distribution of micro-particles is sensitive to the airway geometry and the flow structure in laminar flows, while regional ventilation determines the regional particle distribution in turbulent flows. Laminar flows could potentially be used for parallel targeting with low density gas and/or low flow rate.

Reference

Miyawaki, S., M. H. Tawhai, E. A. Hoffman, and C. L. Lin. Effect of Carrier Gas Properties on Aerosol Distribution in a CT-based Human Airway Numerical Model. *Ann. Biomed. Eng.* (2012), DOI: 10.1007/s10439-011-0503-2

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