Pores of Kohn:

Forgotten alveolar structures and potential aerosol generators?

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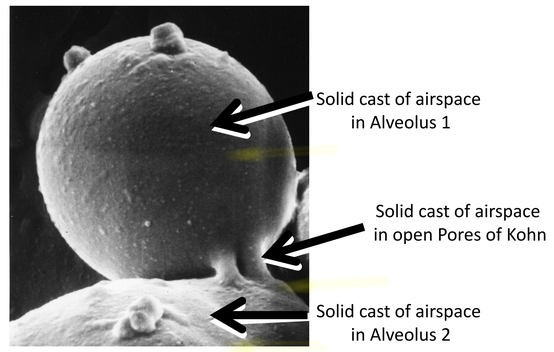

Photograph courtesy of Dr. Phalen at the Air Pollution Health Effects Laboratory, University of California, Irvine.

Background/Synopsis

Analysis of human and animal exhaled breath has identified numerous compounds including proteins and surfactant constituents from the deep lung. Neither deterministic nor computational fluid dynamic models have provided any insight into the potential mechanisms that generate these deep lung proteins and surfactant constituents aerosols. Some mechanisms such as coughing, surfactant/mucus plug, or "bronchiole film burst" have been proposed to explain the presence of these proteins from the deep lung, but do not include possible contributions from Pores of Kohn.

Pores of Kohn are channels between alveoli and have been found in numerous species including humans. Initially, Pores of Kohn were thought to provide collateral ventilation to prevent excessive localized alveolar pressure. Currently they are thought of as fluid filled connections between alveoli and only as collateral ventilation under extreme conditions of alveolar duct or terminal bronchiole blockage. Pores of Kohn have also been hypothesized to be the portals for macrophage movement between alveoli, a potential surfactant reservoir, and the structures that erode during development of emphysema when individual alveoli erode and seem to merge. A re-examination, of the change in diameter/forces exerted by surfactant film in the Pores of Kohn during normal inspiration, demonstrates that these channels should open following rupture of the surfactant film; which can generate aerosols of surfactant film constituents. To more accurately calculate deep airway aerosol generation, clearance, and deposition, Pores of Kohn should be integrated into deterministic and computational fluid dynamic models.

References/Citations

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- Johnson, G.R. and Morawska, L. The mechanism of breath aerosol formation, J. Pul Med Drug Del, 22:229-237, 2009
- Lu D, Stanely C, Nune G, Frazer D. A mathematical description of the pressures in alveolar pores of Kohn, J Biomech Eng. 113:104-108, 1991.
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Proposed Mechanism

There appears to be another mechanism for lung-aerosol production that complements Johnson's and Morawska's (2009) "bronchiole fluid film burst" model. This complementary mechanism involves film breakage during opening of pores of Kohn.

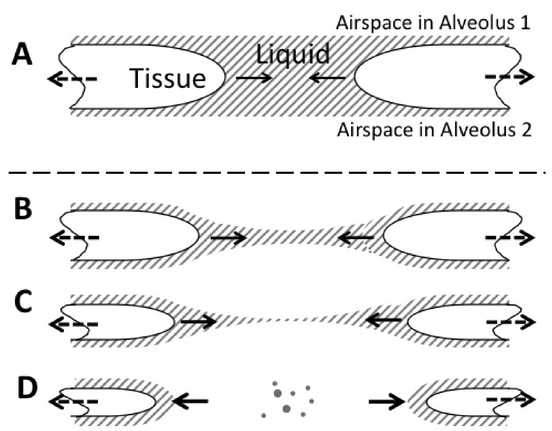

Figure 1: Vertical cross section of a pore of Kohn during inspiration:
"**A**" liquid-filled pore at start of inspiration, indicating lung-induced [**<---**] and liquid-induced [**<—**] pressure on alveolar-wall tissue;
"**B**" and "**C**" liquid-filled pore as inspiration continues, indicating stretching of pore and thinning of alveolar-wall tissue ;
"**D**" liquid-lined open pore following random rupture of liquid film, indicating reversal of liquid-induced pressure on tissue and aerosol production.

In their 1991 paper, Lu et al address the hypothesis that during opening of a pore of Kohn, liquid film rupture produces pressures sufficient to stress and possibly damage lung tissue, initiating an emphysematous disease process. Their calculations, show that this sudden reversal of the direction of liquid induced pressure on walls of the pore can become sufficient to cause tissue damage. However, the authors do not mention that an aerosol is produced when the liquid film ruptures and opens the pore.

The change in alveolar surface area ("A/A_0"), necessary to initiate pore opening, can be estimated when Lu's calculations of a rectangular pore are modified to include change in alveolar-wall thickness ("T/T_0"). A pore with initial radius r_0 should begin to open when …

$$\frac{A}{A_0} = \frac{2}{(T/T_0)} + \frac{1}{12}\left(\frac{T_0}{r_0}\right)^2 (T/T_0)^2$$

- In the unlikely case that alveolar-wall thickness remains constant during inspiration, "$T/T_0 = 1$", pores should begin to open when "$A/A_0 \approx 2$".
- For alveolar-wall thickness a linear function of "A/A_0", such as "$T/T_0 = (-1/6)(A/A_0) + 7/6$", pores should begin to open when "$A/A_0 \approx 3$".

Acknowledgement

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