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Numerical MRI of the translational diffusion in branching three-dimensional labyrinths of a model pulmonary acinus

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Purpose
Different approaches have been used to describe NMR signal attenuation by translational diffusion of hyperpolarized helium-3 nuclei in the human acinus under magnetic field gradient [1-3]. We propose a numerical study to reveal the importance of the branching structure of the acinus. For healthy lungs, such a tree structure provides a rapid access of oxygen to the alveolar membranes [4,5]. In contrast, emphysema may partially or completely destroy the internal structure of the acinus. Our goal is to compare translational diffusion under magnetic field gradient in purely branching and partially destroyed model acini. Its experimental implementation may allow to diagnose early emphysema stages in human lungs due to such geometrical defects.
Method
The internal morphology of the acinus was represented by different three-dimensional Kitaoka labyrinths [6] with a dichotomic branching structure filling the volume and corresponding to the proportion of internal walls ν=0.6 (Fig. 1). The emphysema acini were obtained from these labyrinths by destroying a part of randomly chosen internal walls (ν<0.6). Monte Carlo simulations of the reflected Brownian motion were realized (with one million particles) to compute the NMR signal. An arbitrary acinus orientation in the chest was taken into account by averaging over all possible gradient directions in 3D space.
Results and Discussion
As expected, the successive destruction of the internal walls led to faster diffusion which, in turn, implied larger attenuation. It was found that the NMR signal sharply decreased at early stages, when only a few percents of internal walls were

destroyed, and then slowly approached the signal from a domain with completely destroyed internal structure (Fig. 2). This behavior confirmed a particular role of the branching structure of the healthy acinus and a possibility to distinguish it from emphysematic structures. An experimental study of Kitaoka acinus is now in progress to validate these concepts.

References

[1] van Beek E.J.R., Wild J.M., Kauczor H.-U., Schreiber W., Mugler J.P., de Lange E.E. [2004], J.Magn.Res.Imag. 20:540.

[2] Yablonskiy D.A., Sukstanskii A.L., Leawoods J.C., Gierada D.S., Bretthorst G.L., Lefrak S.S., Cooper J.D., Conradi M.S. [2002] PNAS 99:3111.

[3] Fichele S., Paley M.N.J., Woodhouse N., Griffiths P.D., van Beek E.J.R., Wild J.M. [2004] J.Magn.Reson. 167:1.

[4] Felici M., Filoche M., Straus C., Similowski T., Sapoval B. [2005] Resp.Phys. 145:279.

[5] Grebenkov D.S., Filoche M., Sapoval B., Felici M. [2005] Phys.Rev.Lett. 94:050602.

[6] Kitaoka H., Tamura S., Takaki R. [2000] J.Appl.Physiol. 88:2260.

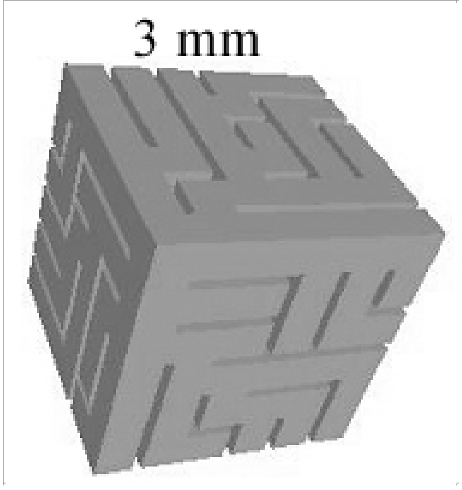

Fig. 1. Branching geometry of one model Kitaoka acinus with 6x6x6 cubic cells of 0.5 mm size. Its total surface area and volume are related to the proportion of internal walls ν in this structure with respect to their maximal number (for the present case, ν=325/540).

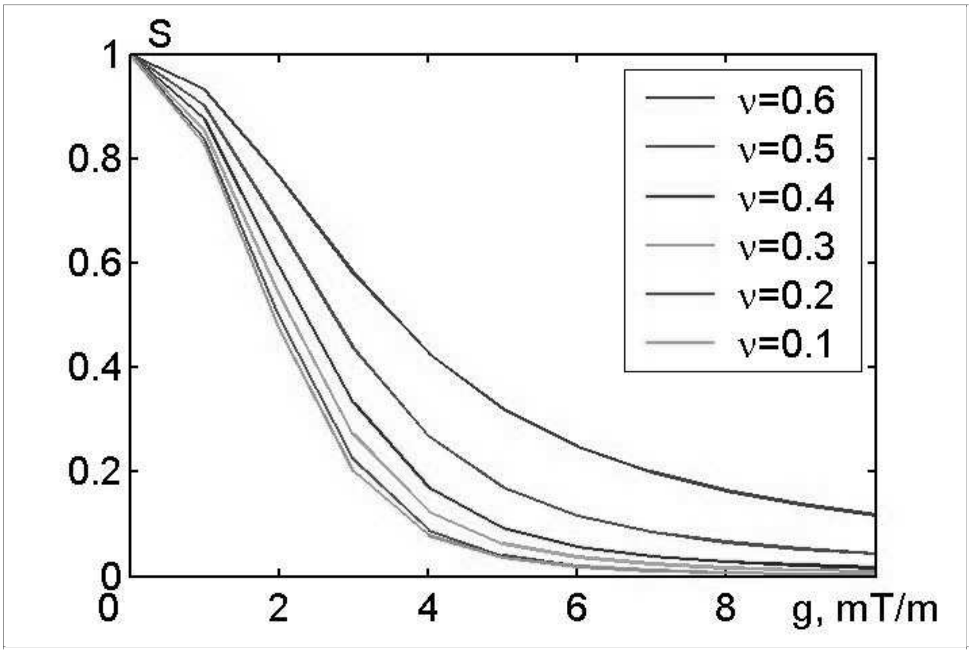

Fig. 2. NMR signal attenuation S as function of the gradient amplitude g after a 10 ms total duration bipolar pulse (with diffusion coefficient D=1 cm2/s) for several values ν of the proportion of internal walls. A small deviation from the healthy acinus structure (ν=0.6) leads to a notable decrease of the signal that may allow to distinguish the healthy acinus from structures with internal walls partially destroyed by emphysema (ν<0.6).

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