MRI Imaging of the Lungs with Hyperpolarized Gases: Current and Future Applications

Justus E. Roos, MD

Outline

How to image Gas with MR

Current Applications

Future Applications

How to image Gas with MR

Adding Function to Structure: Making Inert Gases Visible by MRI

HSSP MRI

Hyperpolarized 3He MRI

Source: H2O

1H density: ~100 Mol/liter

Source: 129Xe gas

129Xe density: ~0.01 Mol/liter

How to image Gas with MR

• 3He and 129Xe polarization ≈10^5 increased
• T1= 2-3hrs once dispensed
• T1≈ 20s upon inhalation (O2)

How to image Gas with MR

The Challenge of $^{129}$Xe MRI

$^3$He MRI circa late 1990’s

$^{129}$Xe MRI circa mid 2000’s

MacFall et al., Radiology 200: 553 (1996)

How to image Gas with MR

Historical price $130/liter

Current price $600/liter

$^3$He $\rightarrow ^{3}$He + e$^+$ + $\gamma$

$^{129}$Xe Safety and Tolerability

1. Inhalation of $^{129}$Xe causes no change in vital signs, ECG, Lab tests
2. Inhalation of 1 liter $^{129}$Xe causes transient symptoms in 91% pts
   - dizziness (50%), paresthesia (30%), hypoaesthesia (30%), euphoria (30%)
3. Inhalation of $^{129}$Xe caused no hypoxia
4. Resolution of symptoms in 1.6 +/- 0.9 min

How to image Gas with MR

Healthy

Asthma

COPD

Small Airways: the “Silent Zone”

PFT: Pulmonary Function Testing

- 100yr old test
- Inexpensive
- Highly variable
- Effort dependent
- “Black box”

Current Applications

Centers for Disease Control and Prevention (CDC) 2011
COPD Before Therapy:

15 min After Salbutamol:

FEV₁ = 28%
FEV₁ = 30%

Asthma:

Baseline: Defect % = 30%
Post Albuterol: Defect % = 19.3%

COPD Functional MR Phenotypes?

New Drug Development

Blood Gas Barrier Impairment

Ventilation is Not the Whole Story

Future Applications
Future Applications

**129Xe Dissolving**

- Moderate Solubility in Tissues (10-20%)
- Large In Vivo Chemical Shift (>200 ppm)

Future Applications

Quantitative 3D 129Xe-Transfer Maps

S. Kaushik et al., J. Appl. Physiol. 2013

Future Applications

**IPF**

- Gas-Transfer gradient: -0.45% cm⁻¹
- Mean Gradient in Normals: 2.00 ± 0.74% cm⁻¹

Future Applications

Spectroscopy

**129Xe Transfer to RBCs**

- 28% of normals
- DLCO 44%

Future Applications

**DermatomyositisILD**

- Reduced 129Xe Transfer to RBCs
- DLCO 44%

Cleveland et al., Plos ONE 2010
Summary

- Direct visualization of airspaces
- Unique strategies for evaluating pulmonary structure and function
  - Visualization and quantification of therapy response
- Diffusion Weighted Imaging contrast
  - Imaging of airspace enlargement, e.g., emphysema
- $^{129}$Xe Ventilation imaging is replacing $^3$He MRI
- $^{129}$Xe Dissolving in lung tissue and blood
  - Imaging gas exchange and uptake

Future Applications

$^{129}$Xe Gas Transfer

$^{129}$Xe-RBC CT

The Team

Bastiaan Driehuys