

Hyperpolarized Gas MRI of the Lungs

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The hyperpolarized gases ^3He and ^{129}Xe are prepared with a magnetization that is 100,000-fold larger than what could be attained by simple thermal equilibrium. This extraordinary magnetization overcomes the low density of these gases and permits them to be imaged with high spatial and temporal resolution. The principles of gas hyperpolarization have been reviewed in a very accessible manner by Goodson [1].

The field of hyperpolarized gas MRI can be traced back to the 1994 work by Albert *et al.*, demonstrating ^{129}Xe MRI of *ex vivo* mouse lungs [2]. Although the field began with ^{129}Xe , the maturity of ^3He hyperpolarization technology and the favorable gyromagnetic ratio of this nucleus led it to quickly become the first agent to be routinely used in clinical research [3, 4]. Accessible reviews on the applications of hyperpolarized gases are provided by Moller [5] and Salerno [6].

Not surprisingly, hyperpolarized gas MRI has found immediate application in pulmonary imaging, since the functioning of the lung is ideally probed by visualizing the distribution of inhaled gases. HP gas MRI has the advantage of being non-invasive and delivering no ionizing radiation, thus making it ideally suited for longitudinal studies and evaluating pediatric subjects. This is particularly vital for monitoring young patients with diseases such as cystic fibrosis, whose need for frequent follow-up requires avoiding ionizing radiation [7]. HP ^3He is also playing a prolific role in asthma research. Particularly intriguing, is the finding that many ventilation defects tend to persist over time or reoccur in the same location within a given asthma subject [8]. ^3He MRI has also recently been used to improve radiotherapy planning by minimizing radiation dose to the well-ventilated lung [9], thereby potentially mitigating complications from radiation-induced pneumonitis.

The contrast from ^3He MRI is not limited exclusively to spin density imaging. The high magnetization permits dynamic imaging of ^3He during inspiration [10] and this technique has recently been extended to 3-dimensions [11]. Arguably the most valuable additional contrast is generated from the so-called Apparent Diffusion Coefficient image (ADC), which reports on the lung's microstructure because the lung constrains the diffusive motion of the ^3He atoms [12]. This constraint is diminished when the alveolar structure is ablated and causing ^3He atoms to become more mobile. This property of the ^3He ADC was recently used to detect early emphysematous changes in asymptomatic smokers [13].

Though ^3He MRI is now in use at over 20 clinical centers worldwide and is shedding light in a variety of areas, its dissemination has been hampered by its regulation as a drug, and the dwindling supply of this scarce resource. Hence for HP gas MRI to become sustainable, a transition is needed to hyperpolarized ^{129}Xe MRI. The development of ^{129}Xe MRI is now accelerating, driven by improved large-scale polarization technology [14], which in turn is making clinical ^{129}Xe imaging more routine [15]. Though some challenges remain for making ^{129}Xe MR images with equal quality to ^3He MRI, ^{129}Xe offers an even broader range of contrast [16] and can be imaged as it transfers from the airspaces to the blood [17] and beyond. HP gas MRI is now turning a corner toward sustainability and broader dissemination, which should drive increasingly relevant clinical applications.

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