STRONG FIELD DEPENDENCE OF HPG-MRI SIGNAL DECAY IN THE LUNG

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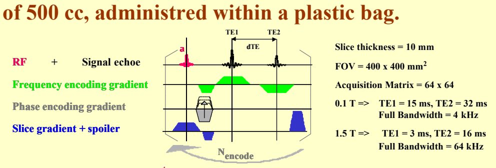
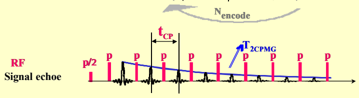
Purpose : MRI with hyperpolarized gases such as ^3He differs from the standard MRI with thermally polarized ^1H because the magnetization M_0 is no more dependent on the static field strength B_0 and is supplied with a limited lifetime. Thus the SNR in the image relies mainly on the ability to accumulate the available signal amount over the full lifetime using dedicated acquisition techniques : an ultimate SNR limit is set by the decay rate of the magnetization once flipped in the transverse plane. In lung ventilation studies the transverse decay is strongly influenced by local conditions including fast gas diffusion, restricted alveolar spaces, and field gradients arising from susceptibility differences at air-tissue interfaces. Our purpose is to evaluate the decay rate at different field strengths.

Material and method :

- Both MRI systems at 0.1 T (Magnetech) and 1.5 T (GE SIGNA), upgraded to handle ^3He signals in the human lung.
- HPG doses equivalent to a few cc of fully polarized ^3He (FPstd cc) , prepared on-site using a homemade optical-pumping system [1], and diluted with inert buffer gas (either ^3He, ^4He or N_2) to reach a total volume of 500 cc, administred within a plastic bag.
- A double-echo FLASH imaging sequence (partial flips of M_0), used to evaluate T_2*, the *free* transverse decay time constant [2,3] :



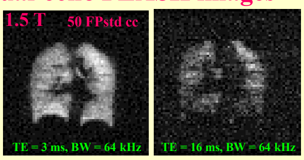
- A CPMG acquisition sequence (total flip of M_0 and repeated 180° pulses), used to evaluate T_{2CPMG}, the transverse decay *under RF refocusing* [4,3] :



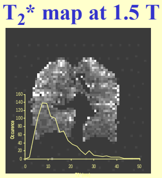
- Experiments at 0.1 T and at 1.5 T, either with the plastic bag (in vitro conditions) filled with the gas mixture containing hyperpolarized ^3He or with healthy volunteers during breath-hold after inhalation of the plastic bag content.

Results :

Dual-echo FLASH images

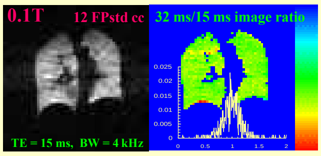


T_2* map at 1.5 T



$<T_2*>$ = 16 ms

Same volunteer at both field strength



the transverse decay is much smaller than image fluctuations !

T_2* map extraction is inaccurate for very long T_2s, due to :
- residual magnet-shimming defects,
- gas diffusion in the image encoding gradients,
- motion artifacts (heart)

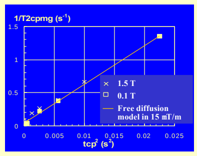
Sum of voxel modules over each image

Overall intravoxel T_2*
1.5 T => 12 - 15 ms
0.1 T => greater than 1 s

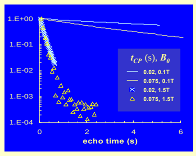
CPMG measurements

In vitro (plastic bag)

$T2_{CPMG}$ as a function of t_{CP} follows a free-diffusion model assuming a linear residual shimming defect of about 15 mT/m with both magnets.

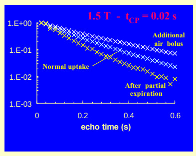


In vivo (normal gas uptake)
- Echo-train attenuation is much faster at 1.5 T than it is at 0.1 T.
- at 1.5 T, $T2_{CPMG}$ varies slightly with t_{CP},
- at 0.1 T, the residual shimming defect still dominates the (very slow) signal attenuation.



In vivo (more or less inflation)

As compared with normal uptake conditions (reproducible within 10%), the decay rate changes significantly following either the addition of an air bolus (30% slower decay) or the partial removal of the gas mixture (30% faster decay).



Overall intravoxel T_{2CPMG}
1.5 T => 138 ± 15 ms
0.1 T => greater than 10 s
at t_{CP} = 20 ms

Discussion/Conclusion :

- Both transverse decay time constants T_2* and $T2_{CPMG}$ decrease by about 2 orders of magnitude when the magnetic field strength is increased from 0.1 T to 1.5 T.
- The long decay time constants at 0.1 T provides means to optimize the SNR and to encode apparent diffusion (ADC) at long time scale (using a late-echo FLASH or a RARE technique [5]).
- Imaging of the pulmonary ventilation at 0.1 T with either a RARE or a narrow-bandwidth FLASH technique requires relatively small HP ^3He doses to achieve a good SNR.
- Regional signal losses with usual protocols at 1.5 T may induce quantification errors in ventilation maps.
- The decay time is shortened by intravoxel processes and contains information about the pulmonary microstructure as explored by the gas diffusion. The information is hardly accessed is the field is too low.

References :
[1] J. Choukeiffe et al., MAGMA **15 suppl. 1**, p. 201 (2002).
[2] A. Vignaud et al., MAGMA **15 suppl. 1**, p. 201 (2002).
[3] P-J. Nacher et al., MAGMA **15 suppl. 1**, p. 222 (2002).
[4] A. Vignaud et al., MAGMA **15 suppl. 1**, p. 200 (2002).
[5] E. Durand et al., Magn. Reson. Med. **47**, 75 (2002).