Signal-to-Noise Ratio for Hyperpolarized 3He MR Imaging of Human Lungs: A 1.5 T vs 3 T Comparison

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Introduction:

Unlike conventional MR imaging, the magnetization in hyperpolarized noble gas (HNG) MR imaging is independent of the magnetic field strength. This means that signal-to-noise ratio (SNR) is expected to be independent of field strength, in the sample-dominated noise regime expected for lung imaging at most clinical field strengths. Furthermore, it has been suggested that the SNR may decline at higher field strength due to decreases in T_2* due to susceptibility increases at the air-tissue interface [1, 2]. To test this hypothesis, the SNR of hyperpolarized ^{3}He lung imaging at two commonly used clinical field strengths (1.5 T and 3 T) were compared in the same volunteers, taking advantage of the identical capabilities to perform human ^{3}He imaging at Robarts Research Institute (3T) and the University of Wisconsin (1.5 T). Both labs used identical pulse sequences and very similar MR imaging systems (GE Healthcare) and RF coils (Rapid Biomedical), Thermally (ie. Boltzmann) polarized and hyperpolarized ^{3}He phantoms were used to correct the human results for any differences in MR imaging system and polarizer performance at the two sites.

Methods:

(1) Thermal Phantom: Images were first obtained from the same thermally-polarized phantom transported to both sites, in order to quantify any differences in system performance (eg. coil performance, noise figure and gain). The phantom consisted of a sealed glass vessel filled with 2.5 atm of ^{3}He and 2.5 atm O_2, the thermal phantom was imaged under identical loading conditions with a 2D fast gradient echo (FGRE) with the following settings: TR=2 s, TE=1.55 ms, FOV= 48 cm slice thickness = 200 mm and bandwidth of 2.0 and 3.9 kHz. To account for any differences in the flip angle at the two sites, constant flip angle (CFA) signal decays from a hyperpolarized syringe were also acquired to determine the flip angle at the same transmit settings, using the same pulse sequence but with the phase encoding gradients turned off.

(2) Hyperpolarized Phantom: In order to quantify differences in polarization at each site, SNR values of a similar hyperpolarized phantom (i.e. 1.0 L Tedlar bag) were measured. The Tedlar bags at both sites were both filled with the same gas mixture as used for the later human study (ie. 350ml hyperpolarized ^{3}He and 550ml of nitrogen). Measurements were performed with the same pulse sequence as used for the thermally-polarized phantom but with ,TR = 4.1 ms, TE= 1.3 ms and band-widths (BW) of 31.25 and 62.5 kHz, since these are the values typically used for human imaging. CFA Flip angles was calibrated as described above. To avoid the effect of CFA acquisition on the non-renewable hyperpolarized magnetization, the signal in all cases was measure based on the central line of k-space, following 1-D FT to yield a profile from which signal was derived from the mean. The standard deviation of the background was used to estimate noise.

(3) Human Imaging: All human imaging was performed following human subjects protocol approved at each site. SNR measurements were repeated with the same volunteers at both sites as described above. In this case, 14 slices were acquire with 15mm thickness, TR= 3ms, TE=1ms and BW = 31.25 and 62.5 kHz.

Results and Discussion:

Table 1 shows the SNR values and flip angles obtained from the thermally-polarized phantom at both sites for each bandwidth. Following correction for the flip angle and the field strength (for thermal polarization), no significant differences in the SNR values were observed, confirming the system performance (eg.coils and noise figures) of the two imaging systems were similar.

Table 1. SNR with thermally-polarized ^{3}He phantom.

Bandwidth	BW 2 kHz		BW 3.91 kHz	
Field strength	**1.5T**	**3T**	**1.5T**	**3T**
SNR	5.01	4.21	3.78	3.07
FA (degrees)	56.67	20.41	56.67	20.41
SNR/(sin(FA)*Bo)	4.00	4.04	3.02	2.94

Table 2. SNR with hyperpolarized ^{3}He phantom.

Bandwidth	BW 31.25 kHz	
Field strength	**1.5T**	**3T**
SNR	24.29	207.23
FA (degrees)	5.02	4.21
Polarization (%)	1.41	19.89
SNR/(sin(FA)*P)	196.84	141.96

Since there were no significant differences observed between the two systems with the thermal phantom, any differences in the measurements with the hyperpolarized bag were anticipated to be due to polarization or polarimetry calibration differences at the two sites. Table 2 shows the apparent polarization values in % reported by the polarimetry station at each site, prior to each SNR measurement (Note: The polarization of the bag at 1.5T was much lower since this bag was also used for flip angle calibrations prior to image acquisition). The corrected SNR (last line in Table 2) at 1.5 T was measured to be 1.39 times higher than at 3 T, presumably due to differences in polarization calibration at each site. This factor of 1.39 was used as a calibration constant to correct the subsequent human SNR measurements. This factor may have been due to differences in calibration factors between polarimetry stations at the two sites and is an area of further investigation. .

Table 3. Hyperpolarized ^{3}He SNR comparison in a healthy volunteer.

Bandwidth	BW 31.25 kHz		BW 62.5 kHz	
Field strength	**1.5T**	**3T**	**1.5T**	**3T**
SNR	28.30±3.28	21.90±2.88	19.47±3.19	16.72±2.50
FA (degrees)	5.02	2.97	5.02	2.97
Polarization (P in %)	15.58	21.29	15.58	20.27
FOV(cm)	40.0	48.00	40.00	48.00
SNR/(sin(FA)*P*FOV)	0.49±0.06	0.41±0.05	0.34±0.05	0.33±0.04

Table 3 shows the mean values of the SNR in the 7 central slices obtained for one of the human subjects imaged at both sites. Also shown are the SNR values corrected for flip angle, polarization and FOV are also shown. No significant differences in corrected SNR in this volunteer were measured between the two field strengths.

Figure 1 shows images of the same subject at 1.5 T and 3 T acquired with a bandwidth of 31.25 kHz. Similar results were found in a second subject imaged at both sites.

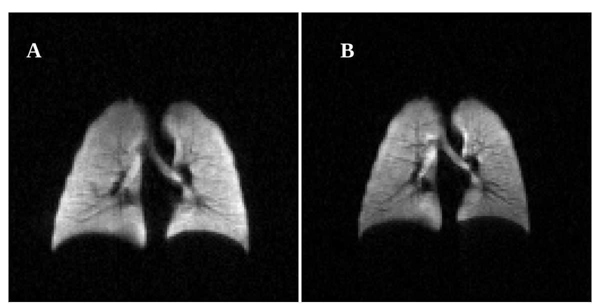

Figure 1. Human lung images of the same volunteer at: (A) 1.5 T and (B) 3 T. Both acquired with a bandwidth of 31.25 kHz

Conclusion:

After correcting for the flip angle, polarization and FOV, no significant differences in the SNR for a giving BW was measured between 1,5 T and 3 T. Clinically, however a higher SNR is anticipated at 1.5 T if the bandwidth can be reduced further to match the longer T2* available compared to 3T [2].

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References:

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