Comparison of 3He ventilation images at 1.5T and 3T: increased apparent heterogeneity due to susceptibility gradients.

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Introduction: The spin polarization of hyperpolarized media such as ^{3}He, ^{13}C and ^{129}Xe does not depend on the static magnetic field strength B_0, hence higher B_0 field strength does not necessarily result in a better signal to noise ratio. While theoretical predictions exist [1], the signal to noise ratio (SNR) for imaging of hyperpolarized nuclei will depend on the size of the object and the RF coils used, thus detailed experimental comparisons of different B_0 field strengths are scarce [2]. In this work, we compare ^{3}He human lung images obtained at the clinically relevant field strengths of 1.5T and 3T, and show that ventilation images at the higher field strength appear more heterogeneous, effects we attribute to B_0 [3] and B_1 inhomogeneity. This has consequences for quantitative markers of ventilation heterogeneity [4, 5].

Materials and Methods: ^{3}He was polarized to ~25% using a prototype spin-exchange polarizer (Helispin, GE). Healthy volunteers inhaled a mixture of 300 ml ^{3}He mixed with 700 ml N_2 from functional residual capacity. Images were obtained from 3 volunteers with Ethics committee approval on a GE Signa HDx 1.5T scanner (GE, USA) using a flexible twin-saddle coil (Medical Advances, USA) and on a Philips Intera 3.0T scanner (Philips, NL) using a Helmholtz coil pair (Pulseteq, UK). A 2D spoiled gradient echo sequence was used to obtain coronal ^{3}He lung images. Imaging parameters were identical on both scanners : flip angle 7°, TE = 1.31 ms, FOV 38 × 38 cm^2 on a 128 × 128 matrix, and 10 mm slice thickness. The receiver bandwidth was 31.25 kHz at 1.5T, and 34.72 kHz at 3T. Phase encoding was sequential in the interest of spatial resolution. The repetition times were TR = 3.9 ms at 1.5T and TR = 4.6 ms at 3T. A difference in TR has negligible influence on image appearance, as magnetization was spoiled.

In addition to their qualitative visual appearance, ventilation images were analyzed for heterogeneity with a sliding neighborhood algorithm implemented in Matlab to map the nearest neighbor coefficient of variation (CoV), defined as the standard deviation of nearest neighbor intensities divided by their mean. A similar analysis has been suggested previously to assess ventilation heterogeneity [5]. A ROI was selected manually, containing both lungs but excluding the trachea and regions of lung parenchyma which did not yield enough signal due to B_1 inhomogeneity (see Discussion). The CoV was then calculated from the intensities of each pixel and its nearest neighbors, excluding pixels outside the ROI to avoid edge artifacts.

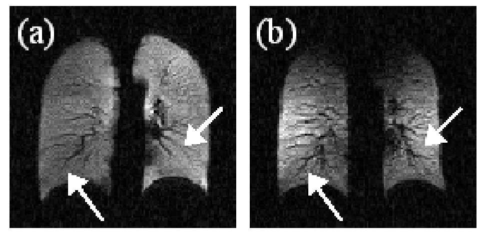

Figure 1: ^{3}He ventilation images from volunteer #1, at 1.5T (a) and 3 T (b). 3 T images have more texture due to susceptibility gradients, e.g. at vessels (arrows). Signal loss at the apexes in (b) is due to B_1 inhomogeneity.

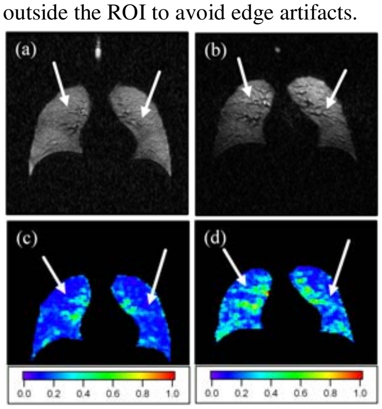

Figure 2: Ventilation images from volunteer #2 at 1.5 T (a) and 3 T (b), and the corresponding CoV maps (c) and (d).

Results and Discussion: Figures 1 and 2 show ventilation images obtained from volunteers #1 and #2 respectively, at 1.5T (a) and 3T (b). SNR was almost identical at both field strengths, with SNR = 9.2 ± 1.3 (mean ± standard deviation) at 1.5T and SNR = 9.2 ± 3.6 at 3T; a direct comparison of the SNR as a function of B_0 is not fully meaningful due to the different RF hardware used. The same anatomical features such as blood vessels are visible at both field strengths; however, at 3T they appear more pronounced, prominent examples being highlighted by the arrows. We ascribe this to the susceptibility difference between vessels and gas spaces, resulting in more dephasing at identical TE according to $\Delta\varphi = -\gamma \cdot \Delta B(\chi) \cdot TE$. In addition to this effect it can be seen that images at 3T suffer from some B_1 inhomogeneity due to the non-ideal spacing of the RF coil loops (deviation from Helmholtz condition), resulting in regions of low signal in central slices, e.g. at the lung apexes in Figure 1 (b). These areas were excluded from the ROI used in the CoV analysis.

In order to quantify texture due to susceptibility effects, the CoV maps shown in Figure 2 (c,d) were calculated. Taking the CoV as a measure of heterogeneity it can be seen that 3T images appear more heterogeneous, with a higher CoV throughout and especially around blood vessels as highlighted by the arrows. Only nearest neighbors were included in the calculation of CoV. We assume that the influence of localized B_1 inhomogeneity can be neglected on the corresponding length scale of ~9 mm as defined by the size of the sliding neighborhood of 3×3 pixels. However, noise will have an influence on nearest neighbor intensity variation. To exclude the possibility that the difference in CoV observed here is merely due to different SNR, the average CoV per slice was plotted versus the slice SNR. Figure 3 shows the result for ten central slices obtained from three volunteers at both field strengths. Images obtained at 3T have a higher average CoV, and appear thus more heterogeneous throughout. The negative slope of CoV versus SNR is a consequence of two effects: the influence of noise on the average CoV, and the fact that central slices have lower SNR with our RF hardware and also contain more large vessels at the same time, leading to a higher average CoV in combination with lower SNR. From Figure 3, it can be seen that the difference in average CoV between both field strengths is independent of these effects, which means that images obtained at 3T appear generally more heterogeneous for identical TE.

Previously, susceptibility effects in ^{3}He imaging have been observed close to the diaphragm at field strengths of 0.54T and 1.5T [2, 3]. The present work focuses on the ventilated lung parenchyma, and shows that at higher B_0 the lungs appear more heterogeneously ventilated due to localized susceptibility gradients. This has consequences when quantifying total lung volume [4] or regional ventilation heterogeneity [5, 6], as the values reported by quantitative methods relying on single ventilation images will depend on the B_0 field strength.

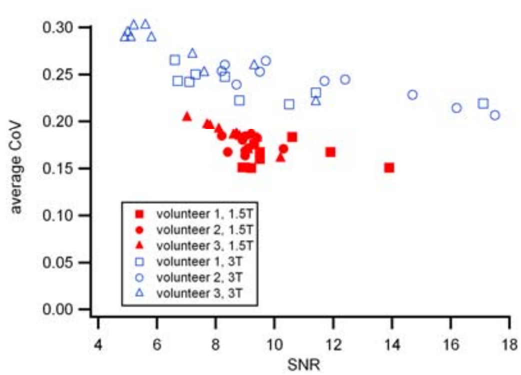

Figure 3: Average CoV of nearest neighbour intensity plotted against SNR. Each point corresponds to one slice.

References: [1] Parra-Robles *et al.*, Med. Phys. 32, 221-229 (2005); [2] Salerno *et al.*, MRM 53, 212-216 (2005); [3] Wild *et al.* MRM 50, 417-422 (2003); [4] Woodhouse *et al.*, JMRI 21, 365-369 (2005). [5] Tzeng *et al.*, Proc. ISMRM Seattle 2006, 1663; [6] Parraga et al., Acad. Radiol. 15, 776-785 (2008).
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