Retrospective Bias Correction of Hyperpolarized ^{3}He MRI of the Lung

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Purpose

To present an algorithm for retrospectively removing the low frequency intensity variation in spin-density hyperpolarized ^{3}He lung images, which is a potential confounder in various MR image analysis tasks. Such artifactual intensity variation is present in hyperpolarized noble gas MR due to flip angle variations caused by the B_1 inhomogeneity of the RF coil. Correction approaches include [1] in which a hybrid pulse sequence was used to map the flip angle inhomogeneity. Our algorithm is a variant of the popular N3 retrospective bias field correction algorithm [2] for removing bias from hyperpolarized ^{3}He images. Equally important is the public availability of our software as open source to the research community [3].

Methods

Whole lung spin-density (ventilation) hyperpolarized ^{3}He MRI datasets of 156 subjects were retrospectively identified for inclusion in this analysis. Axial MRI data were acquired on a 1.5 T whole body MRI scanner (Siemens Sonata, Siemens Medical Solutions, Malvern, PA) with broadband capabilities and a flexible 3He chest radiofrequency coil (IGC Medical Advances, Milwaukee, Wis; or Clinical MR Solutions, Brookfield, Wis.). During a 10-20 s breath hold following the inhalation of approximately 300 mL of hyper polarized helium-3 mixed with approximately 700 mL of nitrogen a set of 19-28 contiguous axial sections were collected. Parameters of the fast low angle shot sequence for 3He MR imaging were as follows: repetition time msec/ echo time msec, 7/3; flip angle, 10°; matrix, 80 × 128; field of view, 26 × 42 cm; section thickness, 10 mm; and intersection gap, none.

To compare our N3 variant (available at http://hdl.handle.net/10380/3053) with the original N3 algorithm (available at http://www.bic.mni.mcgill.ca/software/), we calculated the coefficient of variation (CV) difference before and after bias correction, i.e.

$$\Delta_{CV} = \frac{\sigma_{uncorrected}}{\mu_{uncorrected}} - \frac{\sigma_{corrected}}{\mu_{corrected}}$$

where σ and μ are the standard deviation and mean, respectively, of the intensity in the lung region.

Results

The difference in the coefficient of variation was calculated for each of the 156 subjects using both bias correction algorithms. A paired t-test (one tailed, significance level = 0.05) demonstrated a statistically significant performance difference of our algorithm over the original N3 algorithm (p < 1e-5). Two sets of image results of our algorithm on 2 subjects are given in Figure 1.

Conclusions

We presented a variant of the well-known N3 algorithm for bias correction of ^{3}He lung images and found it to be superior to the original algorithm in this application. This bias field correction may be critical to enabling automated image analysis tasks on ^{3}He images until such time that helium MRI coils with significantly improved B_1 field homogeneity are developed. Furthermore, we have made the software publicly available for people to use through the Insight Toolkit of the National Institutes of Health.

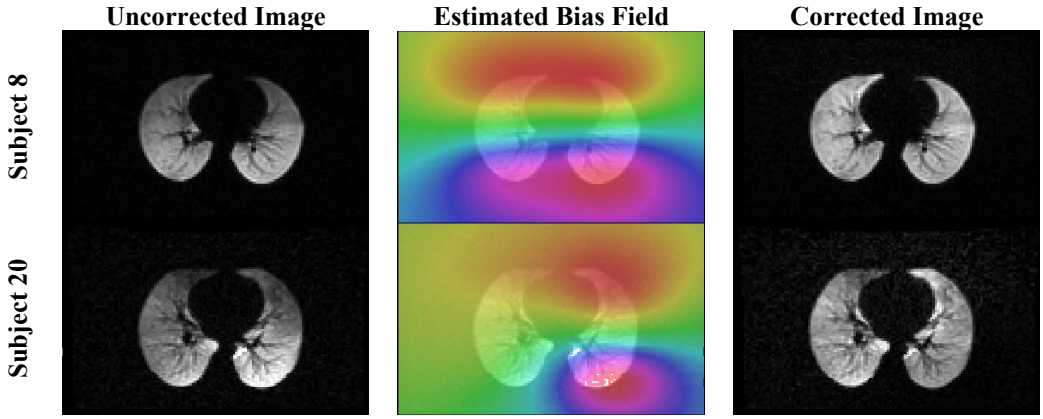

Figure 1. Results of applying our bias correction algorithm to two subjects.

References

[1] Miller et al., MAGMA, 16(5):218-226, 2004.
[2] Sled et al., IEEE Trans Med Imaging, 17:87-97, 1998.
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