Towards automatic image registration of hyperpolarized ^{3}He MRI and x-ray CT images of the lung

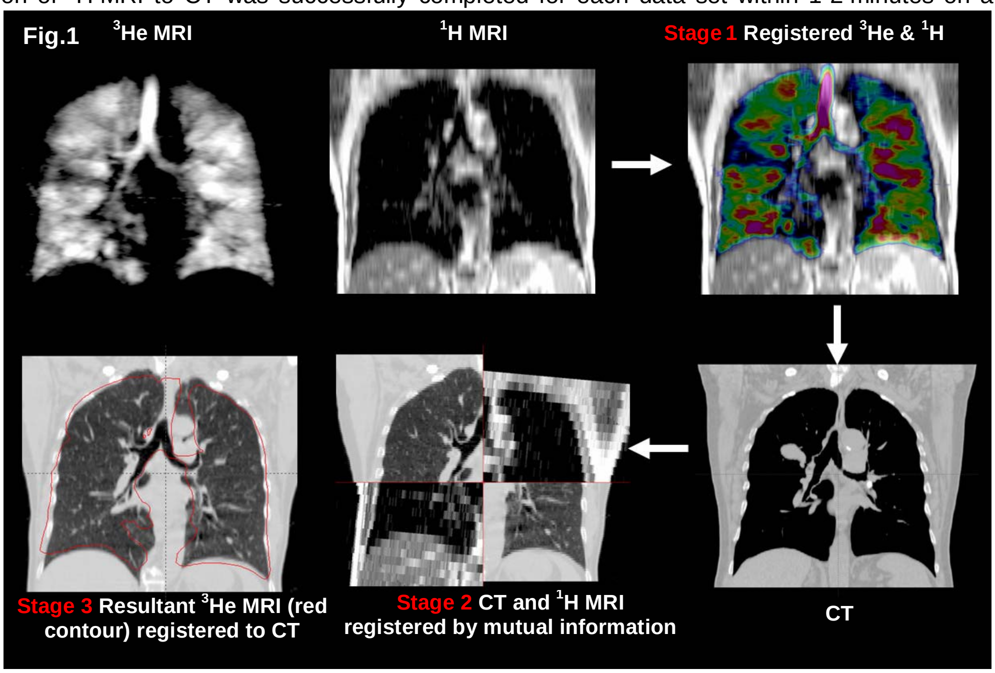
R. H. Ireland[1,2], N. Woodhouse[1], J. A. Swinscoe[2], M. Q. Hatton[2], and J. M. Wild[1]

[1]Academic Unit of Radiology, University of Sheffield, Sheffield, United Kingdom, [2]Academic Unit of Clinical Oncology, University of Sheffield, Sheffield, United Kingdom

Introduction Initial work on ^{3}He MRI to CT image registration [1] demonstrated the feasibility of fusing the images using control point rigid registration. More recently, an enhanced acquisition and registration protocol has been reported [2] that utilizes a new radiofrequency (RF) body coil, a 3D volume ^{3}He MR acquisition sequence, and a multislice radiotherapy CT scanner. Although ^{3}He MRI to CT registration accuracy is improved, the method still requires the input of operator landmarks that have an associated inter-observer variability. Ideally the registration would be performed fully automatically. In this work, an automatic ^{3}He-MRI/CT registration made possible by simultaneous ^{3}He/^{1}H MRI is envisaged. Analogous to the CT component of PET/CT being used as the intermediary for PET image registration [3], ^{1}H MR acquired synchronously with ^{3}He MR in the same breath hold could be used to facilitate automatic ^{3}He-MRI/CT image registration. The purpose of this study, therefore, is to investigate this hypothesis and to develop and test a method that would enable the practical implementation of ^{3}He-MRI/CT registration via ^{1}H MRI.

Methods Nine lung cancer patients due to have radiotherapy gave written informed consent to undergo ^{3}He MRI, ^{1}H MRI and an inspiration breath hold treatment planning CT for a study that was approved by the Local Research Ethics Committee. ^{3}He gas was polarized on site and ventilation images were acquired during a single breath-hold of a 1L ^{3}He/ N_2 mixture. ^{3}He MRI was performed on a 1.5T whole body Eclipse system (Philips Medical Systems), which was fitted with a second RF amplifier (2kW, Analogic Corporation). With patients in the treatment position (arms supported in the upright position), ^{3}He MRI was acquired using an elliptical birdcage coil [4] with a 3D acquisition sequence [5] that consists of a low flip angle (θ=4°), [96, 24] phase encodes in the [y, z] axes, 256 samples in the read encoding direction [x], 9.33mm slice thickness with no gap, FOV=42.6 cm, TE=3.25 ms, TR=6 ms, and bandwidth=31.25 kHz. In addition, axial half Fourier SSFSE breath hold ^{1}H MRI were acquired using a flexible receive-only phased array coil [6]. On the same day, a planning CT was acquired on a 16 slice Lightspeed CT (GE Medical Systems) with arms upright as for the MRI. The planning CT was acquired during a 530 ms deep inspiration breath hold performed with a 1L bag filled with room air that simulated the MRI breathing maneuvers. Imaging was performed at 512x512 pixels per slice with pixel size 0.9766mm and 2.5mm slice thickness. The ^{3}He MR images were transferred to a radiotherapy treatment planning system (Varian Medical Systems Eclipse) for fusion to CT. The image registration is conducted in three stages (Fig.1). First, ^{3}He MRI is registered to ^{1}H MRI using the process of anatomical landmarks [2]. This step would be eliminated by the introduction of a dual acquisition coil and is included here to simulate the process as close as is currently practical. Second, as anatomical information is more readily visualized in the ^{1}H MRI than in the ^{3}He MRI, the ^{1}H MRI can be registered to CT using mutual information [7]. Finally, the required ^{3}He MRI to CT registration is calculated from the initial two image transformations. Registration accuracy was assessed using the relative volume overlap defined as the intersection of CT lung volume and registered MRI lung volume relative to the MR volume [1,2].

Results The mutual information registration of ^{1}H MRI to CT was successfully completed for each data set within 1-2 minutes on a 2.4GHz, 1GB RAM workstation. The mean±SD registration accuracy of ^{1}H MRI to CT was 90.4±6.0%. Registration errors were most prominent at the lung base which is likely to be due to breath hold variability following inter-modality patient repositioning. The registration accuracy for the ^{3}He MRI to CT registration method was 83.4±4.8%.



Conclusions In this work, an additional ^{1}H MRI is used as an intermediate step in the registration of ^{3}He MRI to CT. The supplementary anatomical information provided by the ^{1}H MRI demonstrates the feasibility of applying a mutual information stage in the registration process. Automatic ^{3}He MRI to CT image registration would be less time consuming and more reproducible than a method relying on manual intervention.

Acknowledgments Postdoctoral Award (National Institute of Health Research UK), EPSRC, Weston Park Hospital Cancer Appeal, Sheffield Teaching Hospitals Research Trust, Yorkshire Cancer Research, GE Healthcare, Philips Medical Systems.

References [1] Ireland RH et al. Int J Radiat Oncol Biol Phys 68(1):273-281, 2007. [2] Ireland RH et al. Phys Med Biol 53(21):6055-6063, 2008. [3] Ireland RH et al. Int J Radiat Oncol Biol Phys 68(3):952-957, 2007. [4] de Zanche N et al. Magn Reson Med 60(2):431-8, 2008 [5] Wild JM et al. Magn Reson Med 52(3):673-678, 2004. [6] Woodhouse N et al. J. Magn. Reson. Imaging 21(4):365–369, 2005. [7] Viola P, Wells WM. Int J Comput Vision 24(2):137-154, 1997