The role of hyperpolarized 3-helium MRI in NSCLC

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Introduction

For patients with non-small cell lung cancer (NSCLC), the most common dose limiting complication of radiotherapy is radiation pneumonitis, an interstitial pulmonary inflammation caused by thoracic radiation. The key to lowering the risk of pneumonitis is to reduce the dose to healthy regions of lung while maintaining an adequate dose to the tumor, an approach that requires well ventilated and perfused lung to be identified.

The value of incorporating functional information into lung cancer management has been investigated with SPECT [1]. However, hyperpolarized 3-Helium (^{3}He) MRI has emerged as an alternative lung imaging modality that eliminates the need for radioisotopes and has the potential to provide superior functional information [2]. Although ^{3}He MRI has been shown to detect radiation induced lung injury in rats [3], no previous work has investigated the potential role of *in vivo* ^{3}He MRI for the assessment and radiotherapy treatment planning of lung cancer patients.

One role for ^{3}He MRI could be to enable the calculation of dose-volume histograms that are weighted by functional information, which may be a valuable tool for treatment plan analysis [1]. However, for ^{3}He MRI to be used in radiotherapy, the images must first be registered with the CT acquired for treatment planning. Therefore, the aim of our work is to investigate the feasibility of *in vivo* ^{3}He MR image acquisition and registration to planning CT.

Methods

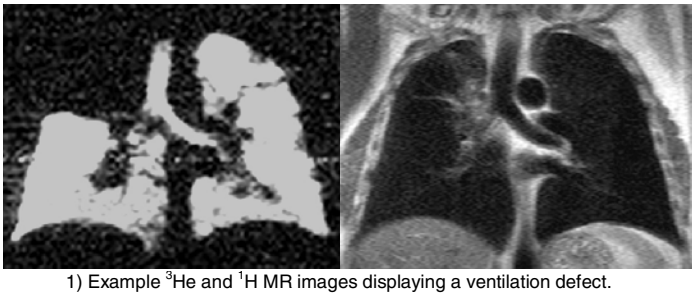
Six patients with NSCLC underwent ^{3}He ventilation MRI in addition to x-ray CT for radiotherapy treatment planning. The patients had histologically proven inoperable NSCLC and had been selected for radical radiotherapy. All patients gave written informed consent to participate and the study had ethics approval. MRI was performed on a 1.5T system modified for ^{3}He protocols [4]. Patients were imaged during a breath hold of ^{3}He gas (Spectra Gases, Huntingdon, UK) polarized on site to 30% by optical pumping with rubidium spin exchange apparatus (GE Healthcare). Syringes that could be filled remotely with ^{3}He or water were placed on the patient's chest to act as fiducial markers. The ^{3}He ventilation images were obtained with a low flip angle, gradient echo acquisition with 112 centric phase encoding views (3). The remaining sequence parameters were: flip angle $\theta = 9°$, 19 coronal slices, 13 mm slice thickness with no gap, FOV = 43 cm, TE = 3.4 ms, TR = 6.7 ms, 128 samples, and bandwidth = 16 kHz. Single shot fast spin echo ^{1}H MR images were also acquired at breath hold (22 coronal slices consisting of 256x256 pixels with 1.6 mm pixel size and 10 mm slice thickness).

Images were acquired on a flat couch top similar to that used during the acquisition of radiotherapy planning CT, although accurate reproduction of patient treatment position was not possible due to the RF coil. On the same day, patients also underwent radiotherapy planning CT with arms raised above the head while breathing freely. Custom software for modifying DICOM files was used to alter the format of the ^{3}He MR images to enable import into a commercial treatment planning system which interpolated the ^{3}He MR images to match the voxel size and orientation of the transaxial planning CT images. Interactive rigid registration tools were then used to register the ^{3}He MRI to the planning CT. Verification of the image registration methodology was performed with a chest phantom that was scanned with the same ^{3}He MRI and CT imaging protocols as the patients.

Results

All six patients tolerated the breath hold MRI image acquisition without difficulty. The complementary data provided by MR imaging with ^{3}He is demonstrated in Fig. 1. A complete obstruction is evident in the ^{3}He MR ventilation image from a patient with a tumor in the right upper lobe that is visible on the conventional proton MRI.

Despite the different body positions when acquiring the ^{3}He MR and CT images, it was possible to register all six patients' ventilation MRI to the planning CT with reasonable accuracy with rigid registration (Fig. 2). The fiducial markers assisted the alignment of the ^{3}He MRI with the external CT contour enabling the fusion of the ventilation MR within the CT lung segments. Calculated from the entire volume, five studies displayed errors in the range of 6-18 mm, while one study contained up to 31 mm misalignment. Many individual slices exhibited minimal ^{3}He MRI - CT mismatch.



1) Example ^{3}He and ^{1}H MR images displaying a ventilation defect.

2) Example registered ^{3}He MRI displayed with the lung and gross tumour volume contours delineated from the axial planning CT.

Discussion

This work has demonstrated the feasibility of acquiring *in vivo* hyperpolarized ^{3}He MRI suitable for image registration to radiotherapy planning CT. Registration of functional data will enable a variety of biological and physical dose properties to be calculated for both the total lung and functionally viable lung, which may be useful for predicting the probability of radiation pneumonitis when treatment planning. Improvements to the technique should be gained through refinement of the ^{3}He MR imaging technique [5] and by the use of nonrigid image registration [6]. Once these issues have been addressed, the next step will be to assess the impact of ^{3}He MRI on treatment plan evaluation. In particular, it should be possible to calculate intensity modulated radiotherapy (IMRT) plans with constraints derived from the functional information provided by ^{3}He images.

References

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