Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCE-MRI) for High-Resolution Lung Perfusion Evaluation in Pulmonary Neoplasms prior to Radiotherapy.

Introduction: Regional lung perfusion assessment using SPECT has been suggested over the years not only to assess the impact of radiation but also to improve treatment planning by sparing high functioning areas. However, the technique suffers from limitations such as low spatial resolution (~ 1 cu. cm.), use of radioactive tracers, and limited anatomical information. To overcome these limitations, we propose using dynamic contrast enhanced-MRI (DCE-MRI) to evaluate pulmonary perfusion. Quantitative imaging of perfusion with MRI has been demonstrated using a gadolinium based contrast agent and employing the techniques proposed by Hatabu et al. This method relies on a single bolus injection of a paramagnetic contrast agent (usually Gd-DTPA) that produces a transient signal enhancement on a T₁ sensitive imaging sequence. By mapping the signal changes into contrast agent concentration curves, one can use techniques developed for indicator dilution to calculate perfusion estimates of pulmonary blood flow (PBF), pulmonary blood volume (PBV), and mean transit time (MTT).

Purpose: While there have been several papers describing DCE-MRI based pulmonary perfusion assessment, there is a dearth of information in the literature evaluating the accuracy of the measurement against a clinical “gold-standard”. Despite limiting factors such as the absence of 3D data and lack of anatomical correlation, scintigraphy V/Q imaging is a well-established clinical test and an accepted “gold standard” of pulmonary function. This work is aimed at demonstrating the utility of DCE-MRI to extract features of pulmonary perfusion and expands its utility in the field of radiation therapy. Furthermore, we hope to validate the use of DCE-MRI for the pre-treatment evaluation of lung perfusion against scintigraphy V/Q studies.

Methods: 3D DCE-MRI and Scintigraphy V/Q studies were acquired prior to radiation treatment in 4 patients enrolled in a prospective study. MRI studies were performed on a 1.5 T magnet (Siemens Healthcare USA Inc, Malvern PA). High-resolution anatomical images were acquired using a T₁W sequence covering the entire lung and was used as the anatomical reference. To achieve a high temporal resolution without sacrificing spatial resolution a FLASH-TWIST sequence was used with a matrix size of 108 × 128, 40 slices of 5 mm thickness, TE = 0.69 ms, TR = 1.62 ms, flip angle = 24°, a bandwidth of 1500 Hz/Px, GRAPPA factor 2 and partial Fourier and phase resolution of 6/8 in both phase encode and slice direction. The typical spatial resolution for each subject was ~3.9mm x 3.9mm x 5mm. After the initial acquisition time of 1.5s, a complete data volume is reconstructed every 1.1s by the TWIST sequence. After acquiring 4 baseline images...
(4.8s), contrast agent (Gd-DTPA, dose 0.1 mmol/kg @ 4ml/s) was injected using a power injector. The subject is instructed to hold their breath at end-exhale for the first 10-12 seconds, and then breathe shallow for the remainder of the DCE-MRI acquisition.

Each DCE-MRI volume is initially registered to the first baseline volume using a non-rigid registration algorithm in IRTK to correct for motion induced by respiration during the scan. Quantitative estimation of blood flow, blood volume and mean transit times, is carried out by an in-house MATLAB ® (Mathworks Inc, Natwick, MA, USA) code that uses signal intensity vs. time images acquired by DCE-MRI to evaluate pulmonary perfusion. The operator is prompted to select a region of interest in the Pulmonary Artery, which is used as the Arterial Input Function (AIF). This AIF is deconvolved using a singular value decomposition method from the signal intensity vs. time image to generate a voxel-by-voxel PBF map. Integrating the DCE curves over the time domain generates the PBV maps. The ratio of the PBF to PBV estimates the MTT maps. The PBF maps were condensed into 2D coronal projections and analyzed using signal intensity counts. Standard clinical protocols were utilized for the acquisition and analysis of scintigraphy perfusion data, which was then compared to PBF using Kendall’s tau correlation coefficients.

**Results:** Figure 1 shows 4 slices of a PBF map overlaid on anatomical MRI images for one patient. The panel highlights the advantages from the 3D coverage and higher spatial resolution, by showing an increased perfusion in the posterior lung fields as would be expected for a patient who is supine in the scanner. Figure 2 shows the changes in signal intensity for selected regions over the time of DCE-MRI acquisition. As expected, we see much higher flow rates in the AIF as opposed to the left and right lungs. Figure 3 shows the corresponding scintigraphy perfusion and DCE-MRI based PBF maps for each patient. A regional analysis using Kendall’s tau rank correlation shows a high correlation (ranging from 0.93-0.96) between the scintigraphy counts and the summation of signal intensity from the PBF maps.

![Figure 3: Top panel- shows images collected using Scintigraphy Perfusion in 4 subjects. Bottom panel- shows the results of PBF extracted using DCE-MRI for the same subjects. C - Kendall's tau correlation and p-value.](image)

**Innovation/Impact:** The benefit of this technique is a significant improvement in spatial resolution (2.5x improvement in in-plane resolution and 2x improvement in slice) over conventional SPECT perfusion. The use of spatially rich functional information has the potential to provide current treatment planning methods with a new dimension that extends beyond anatomical boundaries and could help reduce the adverse effects of radiation therapy. It also has the potential of being developed as a metric for normal tissue toxicity and response.

**References:**