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Lung Imaging and Function Assessment using Non-Contrast-Enhanced Magnetic Resonance Imaging

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Measurement of pulmonary ventilation and perfusion has significant clinical value for the diagnosis and monitoring of prevalent lung diseases. To this end, non-contrast-enhanced MRI techniques have emerged as a promising alternative to scintigraphical measurements, computed tomography, and contrast-enhanced MRI. Although these techniques allow the acquisition of both structural and functional information in the same scan session, they are prone to robustness issues related to imaging artifacts and post-processing techniques, limiting their clinical utilization. In this work, new acquisition and post-processing techniques were introduced for improving the robustness of non-contrast-enhanced MRI based functional lung imaging. Furthermore, pulmonary functional maps were acquired in 2-year-old congenital diaphragmatic hernia (CDH) patients to demonstrate the feasibility of non-contrast-enhanced MRI methods for functional lung imaging.

In the first study, a multi-acquisition framework was developed to improve robustness against field inhomogeneity artifacts. This method was evaluated at 1.5T and 3T field strengths via acquisitions obtained from healthy volunteers. The results demonstrate that the proposed acquisition framework significantly improved ventilation map homogeneity $p<0.05$.

In the second study, a post-processing method based on dynamic mode decomposition (DMD) was developed to accurately identify dominant spatiotemporal patterns in the acquisitions. This method was demonstrated on digital lung phantoms and in vivo acquisitions. The findings indicate that the proposed method led to a significant reduction in dispersion of estimated ventilation and perfusion map amplitudes across different number of measurements when compared with competing methods $p<0.05$.

In the third study, the free-breathing non-contrast-enhanced dynamic acquisitions were obtained from 2-year-old patients after CDH repair, and then processed using the DMD to obtain pulmonary functional maps. Afterwards, functional differences between ipsilateral and contralateral lungs were assessed and compared with results obtained using contrast-enhanced MRI measurements. The results demonstrate that pulmonary ventilation and perfusion maps can be generated from dynamic acquisitions successfully without the need for ionizing radiation or contrast agents. Furthermore, lung perfusion parameters obtained with DMD MRI correlate very strongly with parameters obtained using dynamic contrast-enhanced MRI.

In conclusion, the presented work improves the robustness and accuracy of non-contrast-enhanced functional lung imaging using MRI. Overall, the methods introduced in this work may serve as a valuable tool in the clinical adaptation of non-contrast-enhanced imaging methods and may be used for longitudinal assessments of pulmonary functional changes.