Validation of Two-Compartment Inversion Recovery (TCIR) MRI in a Multimodal Animal Study

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Introduction

Despite physical and technical difficulties, MRI offers a broad spectrum of methods for the relative or absolute evaluation of functional lung parameters. Recently, the non-contrast-enhanced technique Two-Compartment Inversion Recovery (TCIR) was proposed to obtain the fractional pulmonary blood volume (fPBV) quantitatively [1,2]. The method utilizes a half-Fourier single shot turbo-spin-echo (HASTE) sequence together with a global 180° inversion pulse for a measurement series with alternating inversion times (TI). This results in a set of images with varying T_1 contrast which offer the possibiliy to extract the respective fraction of two compartments by fitting a taylored two-compartment model to the data. One compartment being tissue and the other blood. Thus, TCIR provides an approach for the non-invasive quantitative assessment of the regional pulmonary blood fraction. The purpose of this study is the validation of TCIR within a multimodal animal experiment comprising DCE MRI, CT and SPECT.

Methods

The study was approved by the local animal care committee. For the assessment of the performance of TCIR on healthy and pathological specimen, seven anesthetized pigs were studied using a 1.5 T whole-body MR scanner (MAGNETOM Avanto, Siemens AG, Healthcare Sector, Erlangen, Germany) and SPECT (Symbia T, Siemens AG, Healthcare Sector, Erlangen, Germany). The seven mature specimens with a mean weight of 43 kg were placed in supine position, intubated and maintained in general anesthesia throughout the whole experiment. All functional imaging was performed during continued, volume controlled, mechanical ventilation. After the study the animals were euthanized. Prior to the MR and SPECT examination a high resolution CT acquisition was performed in order to generate morphological gold-standard data. For the validation of TCIR, we focused on two examinations. Firstly, the visual comparison of fPBV-maps generated by TCIR to the clinically established DCE MRI and the gold-standard of SPECT on healthy and pathological pulmonary tissue. Additionally, in order to validate the sensitivity of TCIR to changes in the fPBV, the impact of gravitation on the pulmonary blood distribution in anterior-posterior (a.-p.) direction was evaluated and compared to the results of the other methods.

For the calculation of TCIR-based fPBV-maps, sets of 12 coronal and axial lung images with varying inversion time (TI) were acquired using an ECG-triggered HASTE sequence in artificially induced breath-hold. TCIR was performed using the following parameters in coronal direction: TR/TE = 4000/17 ms, slice thickness = 10 mm, FOV = 443x450 mm^2, matrix = 405 x 320, TI = 0, 100, …, 1200, 1500, 2000, 3000 ms, single slice. In order to evaluate the sensitivity of TCIR, the axial acquisition was performed with the following parameters: TR/TE = 4000/17 ms, slice thickness = 10 mm, FOV = 400x263 mm^2, matrix = 256x168, TI analogous).

Each image within every data stack containing a single slice was corrected for residual respiratory motion using a non-rigid registration algorithm with respect to a chosen reference image [3]. Pixel-wise application of TCIR along the alternating TI produced maps of the fPBV.

Subsequent to the MR acquisition the animals were moved to the SPECT. After a time interval of approximately one hour the SPECT examination was started using a dual-head variable-angle camera and ^{99m}Tc labeled albumin macroaggregate.

Results

At this point we would like to present two representative examples of the study. Figure 1 depicts the results of the coronally acquired perfusion measurements of a pig specimen with atelectasis in the upper right lobe. Figure 1a presents the exact anatomical position of the lung. The atelectasis is reflected in a perfusion deficiency in the DCE subtraction image (Fig. 1b), the SPECT acquisition (Fig. 1c) and the fPBV-map in figure 1d. The TCIR-based parameter map clearly delineates the defect as an area of approximately 35% smaller fPBV-values at the same location and similiar spatial dimensions when compared to DCE and SPECT.

Figure 2 presents the results of the sensitivity assessment of TCIR. A visual inspection of the fPBV-map (Fig. 2a), the DCE multiplanar reformatted subtraction image (Fig. 2b) and the SPECT image (Fig. 2c) already points to the suggestion of a sensitivity to gravitation in a.-p. direction. The a.-p. progression of the fPBV, counts and signal, respectively, was evaluated within the marked regions of interest (Fig. 2 a-c). The corresponding pixel-by-pixel progression of the fPBV-values (Fig. 2d), the signal in the DCE image (Fig. 2e) and the count characteristic of the SPECT acquisition (Fig. 2f) illustrate a non-linear dependence on the a.-p. position with a comparable characteristics in all three examples.

Discussion

In this study we validated a new approach for the assessment of the pulmonary blood distribution in an animal experiment under controlled conditions. The presented technique of two-compartment inversion-recovery MRI is based on a non-invasive and contrast media free image acquisitions. The comparison of this functional imaging method to DCE MRI and the gold-standard of SPECT showed good visual correlation in healthy and also pathological lung areas. Whereas a precise quantitative comparison is accompanied by more intensive calculations, the assessment of the characteristics of blood distribution dependence in anterior-posterior directions validates the relative fidelity of TCIR when compared to the gold-standard techniques.

References

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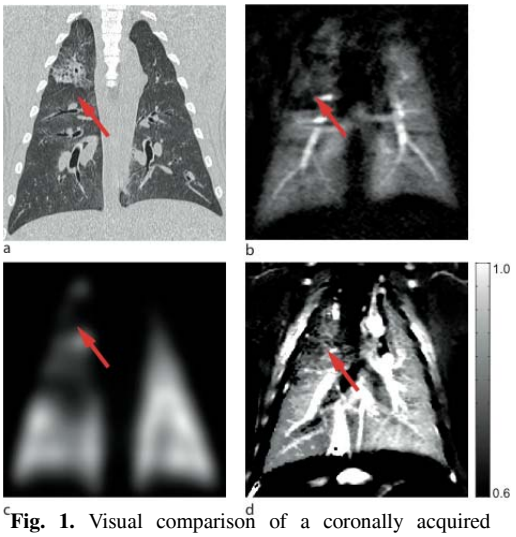

Fig. 1. Visual comparison of a coronally acquired pathological porcine lung with a atelectic region in the upper right lobe; (a) Computed tomography; (b) DCE-MRI subtraction map; (c) SPECT image; (d) TCIR-based map of the fractional pulmonary blood volume.

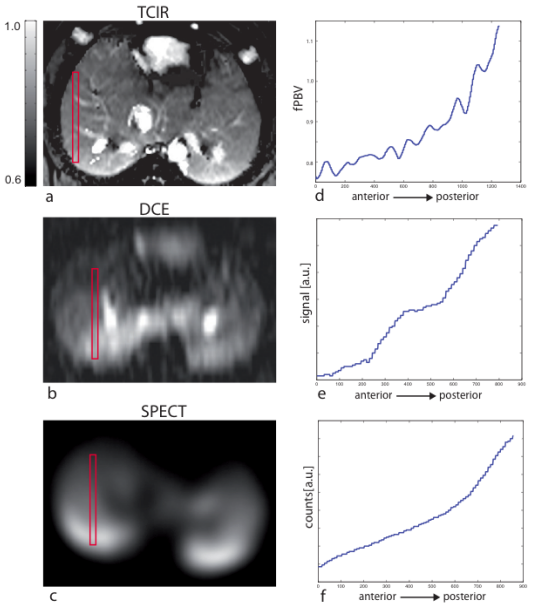

Fig. 2. Assessment of the gravitational dependence of the pulmonary blood distribution. The left column presents the TCIR parameter map (a), the DCE subtraction image, reformated to axial view (b) and the SPECT image (c); The right column illustrates the corresponding pixel-by-pixel characteristics evaluated within the marked regions of interest.