Single Point Imaging (SPI) of lung tissue

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Introduction

The SPI pulse sequence is a pure phase-encode technique that provides true 3D images that are free from susceptibility artefacts [1]. Conventional sequences, which use frequency encoding and slice selection, suffer geometric distortions arising from susceptibility variations. These variations in susceptibility lead to field gradients that rapidly destroy phase coherence in the MR signal. It is for this reason that standard MR sequences need to use extremely short echo times in order to stand a chance of collecting any signal from lung tissue. SPI can be used to image solids with transverse relaxation times down to 10 μs (depending on the gradient capabilities). We have adapted the SPI sequence in order to image rat lung in reasonably short acquisition times. For example a 3D image of size 128x128x32, corresponding to an in-plane resolution of 0.47 x 0.39mm and 1.5mm slice thickness, can be achieved in ~8 minutes. With such a sensitive technique, minimal signal averaging is required. The technique is also relatively insensitive to motion and thus imaging can be performed on freely breathing animals without the need for gating.

Method

Phantom: Images were acquired on 2.35T (Nottingham) or 7T (GSK) Bruker Biospec systems. A lung phantom was created in order to develop and test MR sequences suitable for imaging lung. The phantom consisted of a Ni^{2+} doped agarose gel with appropriate T_1 and T_2 relaxation parameters. Aluminium oxide (Al_2O_3) particles were mixed into the gel, prior to setting, in order to introduce susceptibility variations. Alumina has a magnetic susceptibility twice that of water; thus the field gradients at the alumina/water interface are similar to those at an air/water interface. The presence of the alumina particles creates substantial inhomogeneity resulting in a very short T_2* (~ 1ms), similar to lung tissue. A similar phantom was made comprising a single 5mm alumina sphere in the doped gel. Figures 1 & 2 show three images taken of these phantoms at 2.35T using (a) fast spin-echo (RARE - TE/TR/FA = 15ms/5s/90°), (b) gradient echo TE/TR/FA = 5.2ms/100ms/30°), and (c) Single Point Imaging (t_p/TR/FA = 250μs/1ms/2.5°) sequences. It is clear that the standard sequences do not cope with the magnetically inhomogeneous sample, whereas SPI can detect ample signal and is free from distortions.

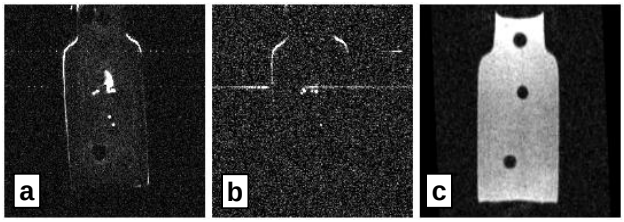
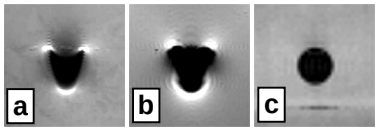


Figure 1. (left) Lung phantom made from agarose gel and aluminium oxide particles used to test MR sequences. **Figure 2. (below)** Phantom consisting of a single 5mm alumina sphere used to highlight geometric distortions that occur in standard sequences. Both phantoms imaged at 2.35T using **a)** RARE, **b)** GEFI and **c)** SPI sequences.



In-vivo: All experiments complied with the UK Animals (Scientific Procedures) Act, 1986 and local ethical guidelines. Healthy male Sprague-Dawley rats (~250g) were anaesthetised with isoflurane. Imaging was performed on the 7T system using a 60mm birdcage coil to acquire volume images of the entire rat thorax. SPI (MTX = 128x128x32; FOV = 8x6x5cm; TR=1ms; FA = 2.5°; t_p = 100μs; Nex = 2; TA = 17mins) was performed on freely breathing rats with and without cardiac and respiratory gating.

Results and Discussion: Figure 3 shows a single slice taken from 3D SPI data sets of a rat thorax acquired with; a) no gating, b) respiratory only and c) respiratory and cardiac gating. The images correspond to 1.5mm thick slices with an in-plane resolution of 0.46 x 0.39 mm. These images clearly demonstrate that SPI is an excellent technique for imaging lung tissue. The method does not suffer from motion artefacts other than slight blurring at the chest boundary, as expected, if no gating is used. A further advantage of using a true 3D imaging method is the ability to reconstruct the image plane in any orientation desired (fig 3d is a reconstructed view of the same data set as 3c). This will allow for better resolution of lung structure than is possible with standard slice selective techniques. The SPI sequence can easily be weighted to enhance T_1 and T_2* contrast. T_1 weighting is achieved by varying FA/TR and T_2* weighting by varying the detection time, t_p (figure 3e shows a T_2* - weighted image using t_p = 200μs). This may be useful in detecting subtle changes occurring in lung tissue as a result of disease states such as fibrosis, as well as the more easily detectable changes due to oedema or inflammation.

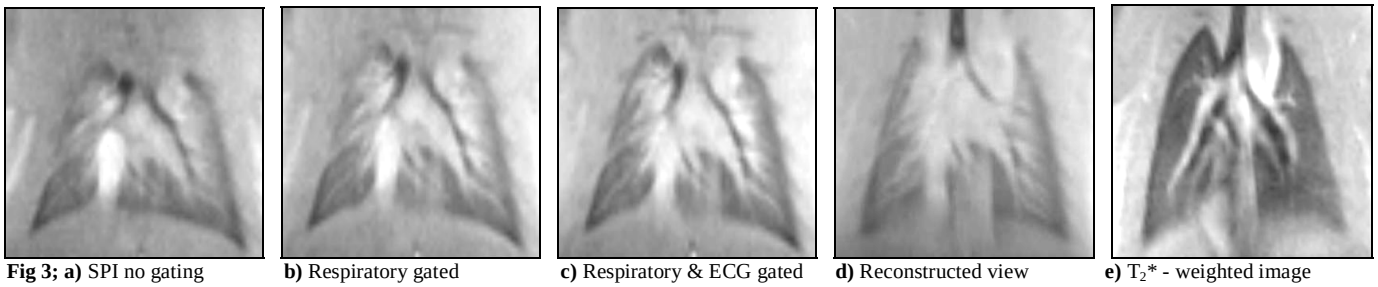


Fig 3; a) SPI no gating **b)** Respiratory gated **c)** Respiratory & ECG gated **d)** Reconstructed view **e)** T_2* - weighted image

Conclusion: Single Point Imaging has proved to be a very sensitive method in imaging lung tissue in-vivo. SPI images that are free from susceptibility artefacts can be obtained in reasonably short acquisition periods without the necessity to use respiratory or cardiac gating.

References: [1] S. Emid, J.H.N. Creyghton, Physica B 128 (1985) 81.

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