Fluorine-19 MRI of the lung: an in vivo comparison of fluorinated gases

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Purpose:

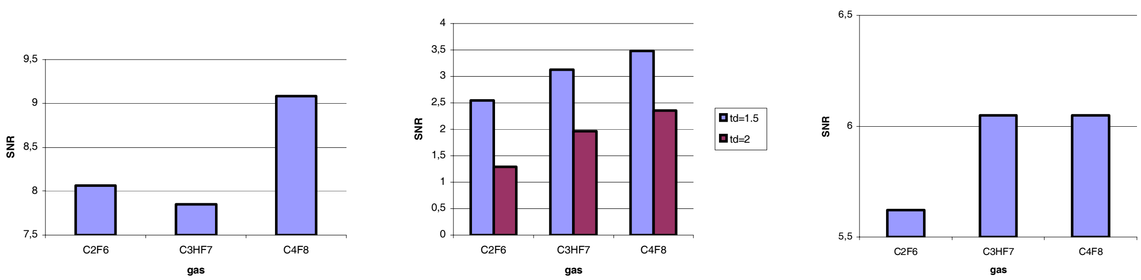
In the past decade, a considerable effort has been put into optimizing imaging techniques using fluorinated gases. [1-4] Among the non-toxic fluorinated gases SF_6 has been tested several times both in small and in large mammals. Also, initial experience has been reported for CF_4, C_3F_8, C_2F_6. To date, it remains unclear, which gas is best suited for imaging of the lung both with respect to image quality and patient safety. To provide data on this issue, we performed a study in healthy pigs, including the gases CF_4, SF_6 and C_2F_6 as well as C_3HF_7 and C_4F_8. The goal of the study was to investigate which gas is best suited for dynamic, as well as single breath-hold static –, 3D and diffusion-weighted imaging.

Materials and Methods

All experiments were run on a 1.5 T MRI scanner (Siemens Magnetom Vision Experimental) using FLASH sequences. The pulse sequence repetition time and echo time TE were adjusted to the individual relaxation times of the gases. 10 healthy pigs (23-26kg) were included in the study. In the first part (n=5), imaging parameters for all 5 gases were optimized for scans during and after completion of a wash-in of gas mixtures of 80% fluorinated gases and 20% O_2; after equilibration of the lung with the inhaled gas mixture, images with subsecond scan times, 3D images and ADC measurements were performed. In the second part of the study (n=5), all imaging techniques were repeated using the optimized parameter settings from the first part. Data analysis comprised a comparison of mean signal-to-noise ratios normalized with respect to gas concentrations measured by a side stream gas analyzer.

Results

SF_6 and CF_4 yield acceptable SNR values exclusively at poor spatial resolution. (data not shown) Fig1a-c show that C_4F_8 is superior to C_2F_6 and C_3HF_7, both in 3D imaging and diffusion-weighted imaging (scan times approx. 1min) while no such pronounced difference is observed for short scan times (t=2s) during wash-in. Fortunately, all the gases were well tolerated by the animals.



a b c

Fig 1a-c: Mean SNR normalized to gas concentrations of 80% and a FOV of 500mm; a: SNR for 5th out of 8 partitions (t=58s); b: diffusion-weighted imaging for td=1.5 and 2 ms (t=59s); c: Maximum SNR per breath (t=2s)

Conclusion

Not surprisingly, the potential use of the gases tested in our study depends on their relaxation times. Particularly for ADC-measurements, which imply long TE (9ms), C_4F_8 (T1=45ms) yields best results followed by C_3HF_7 (T1=20ms).

For the first time, 3D imaging proved feasible *in vivo*. Our study provides first insights into the potential of the 5 gases investigated with respect to the main imaging techniques during a single breath-hold. Our data suggest that fluorinated with relatively long T1 (T1 > 6ms) will provide sufficient SNR in the human lung. As the animals tolerated the breathing of the gases well, there is hope that so will humans. To decide on this important issue of patient safety, additional research is needed.

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