Morphologic 19F-MRI of Perflubron in Pig Lung during Partial Liquid Ventilation

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Introduction
In recent years, perfluorocarbon compounds (PFC) have received increased interest for medical applications because of their high solubility for gases like O2 and CO2 [1]. This characteristic, together with a low surface tension, high vapor pressure and chemical and biological inertness allow them to be used for respiration at acute respiratory distress syndrome (ARDS). In 1991, a new therapeutic strategy was first described by Fuhrmann et al. which is called partial liquid ventilation (PLV) [2].

In PLV, gas exchange is insured during mechanical ventilation by delivering gas tidal volumes into a lung with liquid functional residual capacity (FRC). After intratracheal administration of pure liquid PFC, mechanical ventilation is performed on this PFC filled lung. One important factor for the success of PLV on lung oxygenation at ARDS is the regional distribution of PFC within the lung. Therefore, 19F-MRI of PFC in the lung after its intratracheal administration was expected to provide information about the distribution of PFC in the lung with high spatial resolution.

Methods
All data were acquired on a 1.5 T Siemens Magnetom Vision scanner at a fluoroine frequency of 59.8 MHz. A birdcage RF coil (RAPID Biomedical GmbH, Würzburg, Germany) was used for RF transmission and reception. The fluorinated 19F contrast agent used in the animal study was perfluoro-octyl-bromide (PFOB) C₈F₁₇Br (Alliance Pharmaceutical, Otisville, NY).

Reference measurements were performed in one healthy, anesthetized pig under conditions of partial liquid ventilation. The lung was filled with a dose of 20 ml/kg body weight PFOB, and the animal was then ventilated with an inspiratory oxygen fraction FIO₂ = 100%. Data were acquired during end-expiratory breath hold.

The identical measurement was performed in one anesthetized pig after induction of acute lung injury. ARDS was induced by intravenous injection of 0.15 ml/kg body weight oleic acid (C₁₈H₃₄O₂) mixed with 10 ml of blood. Directly after induction of acute lung injury, the lung was filled with PFOB and ventilated as described above.

19F-MRI of PFOB in the lung was performed using a chemical-shift-selective T₁-weighted gradient echo pulse sequence [3]. Two frequency-selective gaussian-shaped RF pulses were used for presaturation of the two unwanted resonance lines of PFOB. Data acquisition parameters of subsequent FLASH read-out were as follows: imaging matrix of MA = 48 x 128 interpolated to 256 x 256 in three axial slices with THK = 15 mm, FOV = 140 x 280 mm, TR/TE/a = 55 ms/5.3 ms/25°. The resulting in-plane resolution was 3.1 x 2.3 mm². The total acquisition time for 12 averages per slice was 34 s.

Results and Discussion
Figure 1 shows the chemical-shift-selective T₁-weighted images of PFOB in all three axial slices of the healthy pig lung. The maximum signal-to-noise ratio (SNR) was 14.5. All images were completely free from chemical-shift-artifacts, revealing that the presaturation scheme used in our sequence was successful.

Due to the high spatial resolution in the images, anatomic structures (trachea and main bronchi) of the lung are visible as shown in Figure 1. At cranial slice position, a subcutaneously implanted vial filled with pure PFOB is seen. The distribution of PFOB in the lung is seen to be homogeneous throughout all three slice positions.

19F images of PFOB in the lung after induction of ARDS are shown in Figure 2. The maximum SNR was 8.4. The images reveal that the regional distribution of PFOB in the injured lung is significantly different from the healthy lung. The distribution of intratracheally administered PFOB is seen to be rather inhomogeneous throughout the lung. Obviously, not all regions in the lung are filled with PFOB, the reason of which might be found in a higher degree of severity of the induced lung injury in these regions. This would result in a lower FRC and thus a less efficient oxygenation at mechanical ventilation.

Figure 1: 19F images of PFOB in the lung of a supine, healthy pig under conditions of PLV. The images were acquired at caudal (left), central (mid) and cranial (right) slice positions. RL and LL denote right and left lung respectively. At the central slice position, main bronchi are visualized (small arrows), in the cranial slice, a vial filled with pure PFOB (big arrow) and the trachea (asterix) are seen.

Figure 2: 19F images of PFOB in the lung of a supine pig after induction of acute lung injury and under conditions of PLV. The images were acquired at caudal (left), central (mid) and cranial (right) slice positions. RL and LL denote right and left lung respectively. At the caudal and central slice positions, main bronchi are visualized (small arrows), in the cranial slice, the trachea (asterix) is seen. Regions which were not reached by PFOB are marked by circles.

Conclusions
It was shown that morphologic 19F-MRI of perflubron in the lung under conditions of partial liquid ventilation is possible even after induction of acute lung injury. The regional distribution of intratracheally administered PFOB is directly displayed during a single end-expiratory breathhold period. The presented technique is therefore expected to yield new insights into the pathophysiologic mechanisms of experimentally induced ARDS.

References

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