Oxygen-sensitive ^{3}He-MRI – Intrapulmonary oxygen partial pressure and its distribution in lung transplant recipients

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Rationale:

Pulmonary function tests are the standard method for regular monitoring of lung transplant recipients. An otherwise unexplained drop of the forced expiratory volume in one second (FEV1) for more than 10 % of the baseline is defined as suspicion of bronchiolitis obliterans syndrome. ^{3}He-MRI has been shown to be a sensitive method to detect ventilation disturbances in patients with different kinds of lung disease as well as in healthy smokers [1], and there are also hints that ^{3}He-MRI might be a tool for early detection of obliterative bronchiolitis (OB) [2]. As airway obstruction leads to hypoventilation before non-ventilation the alveolar oxygen partial pressure might drop before a visible ventilation defect occurs. This study intends to investigate oxygen sensitive ^{3}He-MRI in the assessment of lung transplant recipients and to elucidate if it can detect differences in intrapulmonary oxygen partial pressure between lung grafts affected by OB and normal grafts.

Materials and Methods:

A total of 15 datasets of oxygen sensitive ^{3}He-MRI were included in a retrospective evaluation. Of these datasets, eight were from patients with normal lung grafts, seven from patients with BOS. Patients were between 39 and 61 years of age (median 51 years). Four patients were double lung recipients, the remaining eight patients were single lung recipients. Images were transferred to a commercially available personal computer. An in-house developed software [3] based on PV-Wave (Visual Numerics, Boulder, California, USA) was used for calculation of the imtrapulmonary pO2. The software calculates the intrapulmonary pO_2 following the physical relationship between noise-corrected signal intensity (A) decay in two series of n images each, taken at different interscan delays t1 and t2, and PO_2: $\ln(An,t1/A0) - \ln(An,t2/A0) = f(PO_2)$. Results are displayed in color coded maps. To account for image noise the matrix of the maps was chosen coarser than that of the source images. For the current evaluation, matrix size was 64 x 64. The software calculates mean pO_2 and its standard deviation as well as the oxygen decrease rate in apnea during the imaging period (RO_2). By manual segmentation only the grafts were evaluated in case of a unilateral lung transplant. Median and quartiles were calculated from each patient's mean pO_2, standard deviation of pO_2 and mean oxygen decrease rate RO_2 during apnea.

Results:

Median intrapulmonary pO_2 in the patients suffering from BOS was 109.9 mbar (quartiles 96.2, 129.7) opposed to a median pO_2 in the patients with normal lung grafts of 146.3 mbar (quartiles 136.4, 157.7mbar). Median standard deviation of pO2 was 42 mbar in BOS patients *versus* 34 mbar in those with normal lung grafts. The oxygen decrease rate during breath hold RO_2 was lower in BOS patients (median, -0.53mbar/sec, quartiles –0.93, 0.19 mbar/sec) than in unaffected patients (median, -1.75 mbar/sec, quartiles –2.44, -1.36 mbar/s). Color coded maps allow for distinction of patients with normal distribution of pO_2 and those with lowered and inhomogeneous pO_2 distribution due to BOS (Fig. 1).

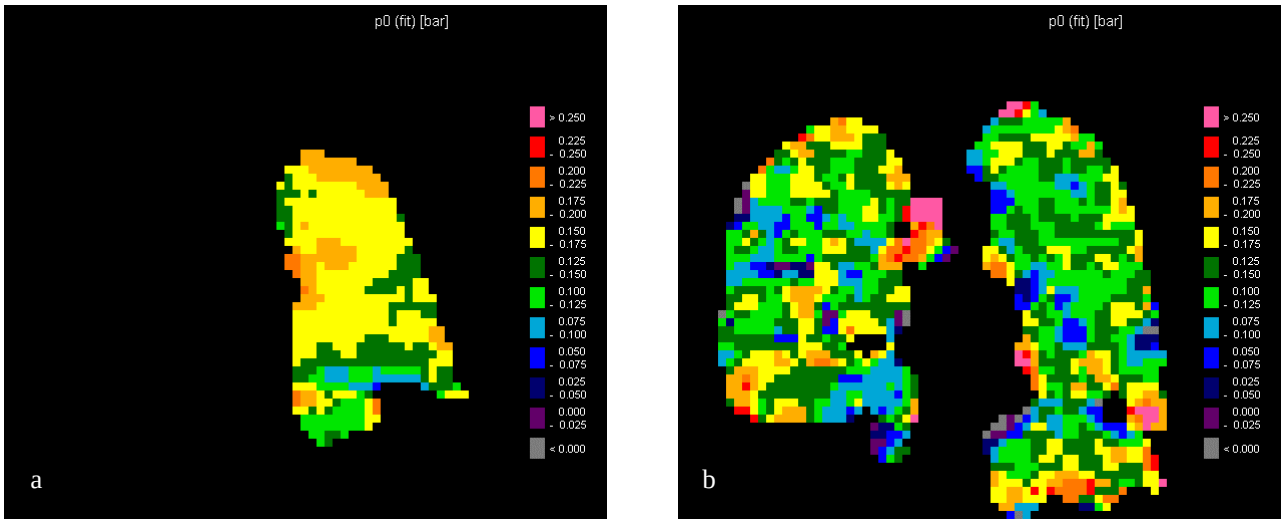

Fig. 1.: (a) 48 year old female after left sided lung transplantation with no clinical history of OB. (b) 48 year old male patient after double lung transplantation with clinical histoy of OB. Intrapulmonary distribution of pO2 is lower and more inhomogenous in OB than without.

Discussion and Conclusion:

Intrapulmonary pO_2 is a result of a steady-state balance between ventilation and perfusion. As BOS is a disease which takes primarily place in the small airways, ventilation is restrained in an affected lung area. Perfusion might be mitigated as well but is only secondarily changed by the Euler-Liljestrand mechanism. In a status of restrained ventilation intrapulmonary pO_2 is expected to be reduced. The reduced pO_2 as well as the greater inhomogeneity of its intrapulmonary distribution could be shown by oxygen sensitive ^{3}He-MRI. The oxygen decrease rate during apnea RO_2 is smaller in BOS-patients than in those with normal transplants. It could be shown that the method detects reduced pO_2 and a more inhomogeneous intrapulmonary pO_2 distribution in patients suffering from BOS in parts of the lung which are still ventilated well enough to show good signal intensity. This is an important information because the measurement takes place in lung areas which should be the least affected by BOS. Thus, oxygen sensitive ^{3}He-MRI might be capable of indicating BOS earlier than spin density measurements.

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