HP ^{3}He-MRI of the exponential alveolar pO_2 decay in human subjects

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Purpose: The local measurement of the alveolar partial pressure of oxygen (pO_2) and its temporal evolution has been shown useful in gas exchange assessment both in healthy subjects [1] as well as in patients [2,3]. The alveolar pO_2 measurement in humans is currently being performed based on the linear model of pO_2 decay during apnea. However, this model is known to be valid for short periods of breath-hold only. The aim of this work was to verify the potential advantages of using the more physiologically appropriate exponential pO_2 decay model [4] for improving the results of pO_2 mapping in humans.

Methods: With local research ethics committee approval 7 subjects were recruited for the study. The acquisitions were performed on a 1.5T clinical Sonata MR scanner. For each acquisition a mixture of 200 ml nitrogen and 300 ml of clinically certified highly polarized ^{3}He was used. The subjects were instructed to perform profound exhalation followed by inspiration of the mixture from a Tedlar bag. For pO_2 measurement a series of spiral projection images with an inter-image delay of either 3s or 4s was acquired. The following sequence parameters were used: 10 interleaved spirals/image, TR/TE=18/2.4 ms, FOV=219 mm, pixel size=1.6x1.6 mm^2. The total acquisition time was 20s or 26s depending on the inter-image delay time. The parametric mapping was performed using two models of pO_2 decay: the linear model: $pO_2(t) = p_0$-Rt, where p_0 is the initial oxygen partial pressure and R denotes the oxygen depletion rate, and the exponential model: $pO_2(t) = p_0\exp(-t/r)$, where r denotes the oxygen depletion time constant. Pixels were excluded from the maps if the values significantly exceeded the physiological limits. Numerical simulations were performed in order to compare the performance of both fitting approaches. The exponential pO_2 decay was simulated assuming p_0 = 120 mbar and r = 35 s with 10% of variation of each parameter. Gaussian noise was added in order to match experimental SNR. The linear fitting was performed and the distributions of the simulated exponential decay parameters (p_0, r) and estimated linear parameters (p_0, R) were compared.

Results: The typical parametric maps of p_0, R and r together with the corresponding histograms are presented in Figure 1. Similar p_0 distributions were observed for both types of fitting procedures. However, better maps were obtained with the exponential model (lower number of pixels excluded from the maps, more uniform distribution of p_0). The maps of the oxygen depletion related parameters (R, r) were more uniform in case of the exponential fitting. Moreover, the distribution of the oxygen depletion time constant (r) was closer to Gaussian as compared to the one of the depletion rate (R). The mean parameter values for the whole group of subjects are summarized in Table 1. Figure 2 and Table 2 represents the results of the numerical simulation.

Fig. 1. The comparison of typical parametric maps of p_0, R and r together and the corresponding histograms.

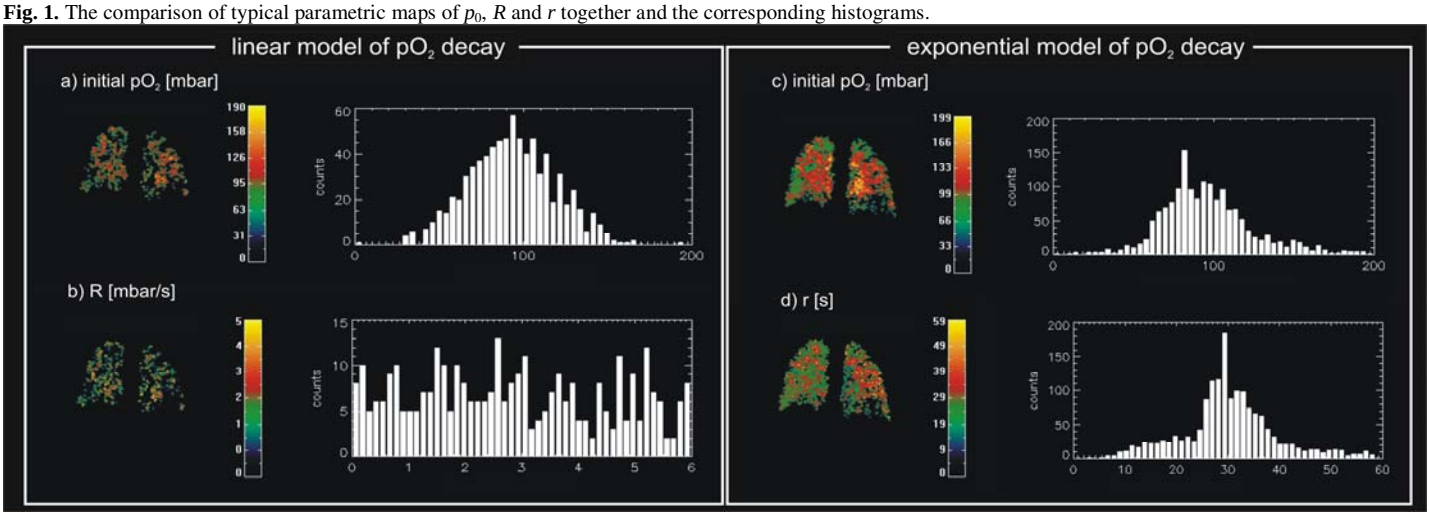


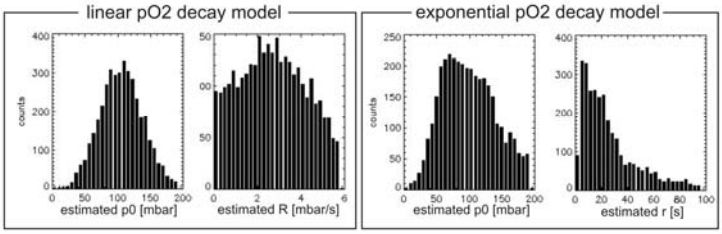
Table 1. Mean values of p_0, r and R measured for all subjects.

exponential pO_2 decay model	linear pO_2 decay model
p_0 = 95.7 ± 8.2 mbar	p_0 = 97.8 ± 8.9 mbar
r = 31.2 ± 4.0 s	R = 2.49 ± 0.61 mbar/s

Table 2. Mean values of p_0, r and R for the simulated data sets.

simulated parameters (exponential model)	estimated parameters (exponential model)	estimated parameters (linear model)
p_0 = 120 ± 12 mbar	p_0 = 116.9 ± 12.1 mbar	p_0 = 117.1 ± 11.5 mbar
r = 35.0 ± 3.5 s	r = 31.8 ± 7.9 s	R = 2.77 ± 0.58 mbar/s

Fig. 2. Comparison of parameters distribution – simulation results.



Conclusions: No significant differences between the mean p_0 values measured using the linear and exponential approach were found. However, higher quality maps of p_0 were obtained using the exponential model as compared to the ones obtained by using the linear model. Moreover, the assessment of the oxygen uptake by the vascular system was found to be more accurately represented using the exponential model. The distributions of the parameters of interest obtained as a result of the numerical simulations confirm the trends observed in *vivo*. In particular, the distribution of R is far from being Gaussian. In conclusion, the use of the exponential pO_2 decay model seems to be better suited for pO_2 measurement, as compared to the linear one, even for relatively short breath-hold periods.

References: 1. Deninger A et al., J Magn Reson 141:207 (1999), 2. Gast K et al., ISMRM 2005, #1819, 3. Lipson D et al., ISMRM 2006, #39, 4. Cieslar et al, NMR in Biomed, 20:383 (2007)