# Dependency of Oxygen Extraction Calculations from a Static Dephasing Model on Capillary-Radius and Volume Fraction

A. Bongers[1], H. Schroeder[2], L. R. Schad[2]

[1]mediri GmbH, Heidelberg, Germany, [2]Medical Physics in Radiology, German Cancer Research Center, Heidelberg, Germany

**Introduction:**

Due to the blood oxygen level dependent (BOLD) effect, oxygenated and deoxygenated blood have different magnetic susceptibilities. Thus, by measuring the susceptibility difference $\Delta\chi$ between capillaries and tissue, one can in principle evaluate the Oxygen extraction fraction from blood (OEF) [2]. A simple dephasing model proposed by Yablonskiy [1] is commonly used to fit the measured signal decay around a spin-echo to determine the reversible relaxation rate $R_2^{'}$ and the blood volume fraction $\lambda$. According to the model, the resulting susceptibility differences should be independent of both $R_2^{'}$ as well as $\lambda$. This is indispencable for the applicability for *in vivo* applications. To test the dependency of values calculated from the static dephasing model on capillary radius a phantom was constructed that simulates the tissue properties of statistically distributed capillaries in a homogeneous medium as required by the model used for parameter evaluation. With this phantom the dependency of calculated susceptibility differences on capillary radius and volume fraction was investigated.

**Methods:**

A custom-built phantom that simulates the tissue properties of statistically distributed capillaries in a homogeneous medium as required by the model was used for parameter evaluation. It consisted of eight compartments containing randomly coiled polyamid strings of different radii ($r_c$= 13.5µm, 19µm, 24µm, 33µm, 44.5µm, 72µm, 97µm, 119µm). The relative volume fraction within the compartments could be adjusted between 3 and 12%. Measurements were performed at blood volume fractions of 3, 5, 7 and 10%. The capillary diameters were chosen to resemble a wide range of capillary and vessel diameters expected in the human brain. The susceptibility difference between strings and surrounding solution was determined by measuring the reversible relaxation time and volume fraction with a home-built combined gradient-echo/spin-echo sequence. On a 1.5T whole body system (Siemens Symphony) 32 gradient echos were acquired arround a spin echo at $TE_{SE}$=150ms. The echo spacing was $\Delta$TE=4ms. Other sequence parameters were: 1st GE: $TE_{GE1}$=82ms, RO-bandwidth=500Hz, TR=2000ms, FOV=192x192mm, Matrix=128x128, $\Delta x=\Delta y$=1.5mm, $\Delta z$=8mm, 32 averages. Homogeneous ROIs were specified within the phantom compartments. Data evaluation was conducted using a modified method of Yablonskiy [3,4].

**Results:**

Fig.1 shows the resulting susceptibility differences against the volume fraction for all eight diameters. Apart from minor fluctuations probably due to fluctuations in the density of capillaries within the compartment $\Delta\chi$ does not show a strong dependency on relative volume fraction. This is in agreement with the predictions from the model.

Fig.2 shows the evaluated susceptibility differences plotted versus the string diameter. The measurements shown here were conducted at a relative volume fraction of 5%, which matches the average blood volume fraction in grey matter. As can be seen the measured data clearly indicate a diameter dependence of the evaluated $\Delta\chi$, which is probably due to shortcomings in the model used for data evaluation. The measured susceptibility difference values range from $\Delta\chi=0.28*10^{-7}$ for the smallest diameter to $\Delta\chi=0.45=0.28*10^{-7}$ for the largest diameter in the phantom, which corresponds to a range of values of >50%.

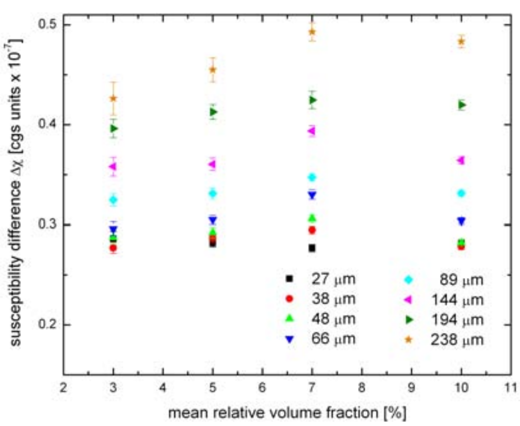


**Fig. 1** Dependency of calculated susceptibility differences on volume fraction of the capillaries within the phantom compartment

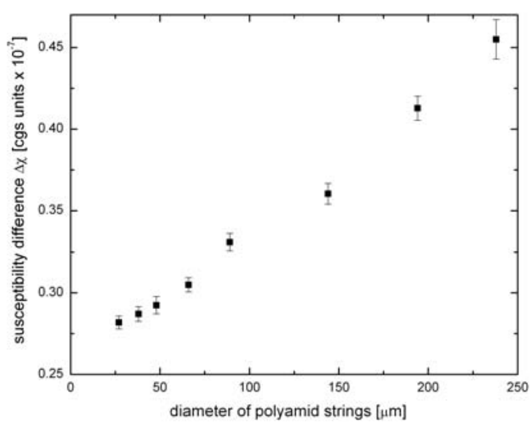


**Fig. 2** Dependency of calculated susceptibility differences on diameter of the capillaries within the phantom compartment

**Discussion:**

When using the static dephasing model [1] to evaluate our phantom measurements the results obtained for $\Delta\chi$ show a clear dependency of the evaluated susceptibility differences on the string diameter. A possible explanation for this might be a major shortcoming in the model. One plausible reason for this might be the increasing effect of diffusion with decreasing capillary diameter since the model does not account for this. As Kiselev and Posse could show, signal behaviour in a spin echo experiment changes for small diameters due to diffusion effects [5]. Hence, our results rise doubts to the feasibility of OEF measurements employing this tissue model, since due to diffusion OEF values might become dependent on capillary radius and radius distribution is not known *a priori*. For a reliable quantification of OEF employing this method, the influence of diffusion effects must be investigated further *in vitro* and *in vivo*.

**References:**

[1] Yablonskiy, Haacke, *Magn Reson Med* **1994**, *32*, 749. [2] H. An,W. Lin, *Magn Reson Med* **2002,** *47*, 958., [3] Bongers, Schad, Proc. Intl. Soc. Mag. Reson. Med. (ISMRM) **2004** *11*, Kyoto, Japan, 1083. [4] Yablonskiy, *Magn Reson Med* **1998**, *39*, 419. [5] Kiselev, Posse, *Magn Reson Imaging* **1999**, *41*, 499.