Effects of several carbogen concentrations on signal changes in susceptibility weighted imaging (SWI)

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Purpose: Inhalation of carbogen (5%CO_2 / 95%O_2) [1] increases cerebral blood flow dramatically and induces BOLD-related signal changes, which yield information about tissue perfusion, oxygenation and potentially sensitivity of tumour tissue with respect to chemo- or radiotherapy [2]. However, such a high CO_2 content of 5% causes patient discomfort due to the forced strong and deep breathing leading to motion artefacts in MR-imaging which interfere with the obtainable BOLD-signal changes [3]. In this study systematic investigations on volunteers were performed by using SWI [4] to confirm a CO_2-concentration below 5% for which BOLD-changes are still detectable and patient discomfort as well as motion artefacts are reduced [5].

Methods and Materials: High-resolution SWI data of 14 volunteers were acquired using a fully velocity-compensated 3D gradient-echo sequence (TE/TR/FA=40ms/57ms/20, FoV=256x192x64mm^3, matrix=512x156x38, voxel size=0.5x0.75x2mm^3) at 1.5T (Magnetom Vision, Siemens). Carbogen (5%CO_2 / 95%O_2) was mixed with pure oxygen (100%O_2) using a cPAP-System (CF800, Dräger) to obtain different CO_2-concentrations (0 / 1.67 / 3.33 / 5% CO_2). For each volunteer four SWI-scans were acquired with increasing CO_2-concentrations and interpolated to a voxel size of 0.5x0.5x1mm^3. The four volumes were coregistrated using AIR [5] followed by ROI-based analysis in 4 cortical and 9 deep veins in the brain where the relative signal changes were determined. Finally, a t-test was performed to test for statistical significance.

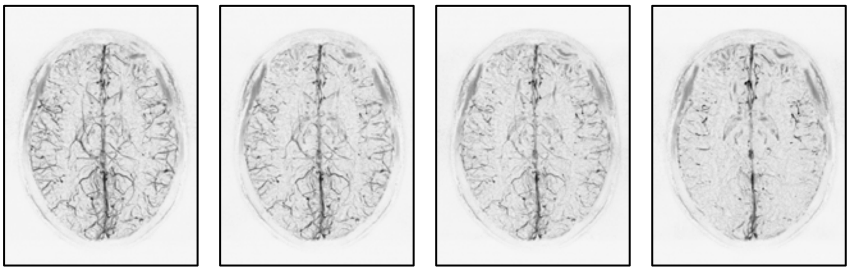

Figure 1: SWI data for 0%, 1.67%, 3.33% and 5% CO_2 (from left to right) clearly visualize the loss of venous contrast with increasing CO_2-concentration.

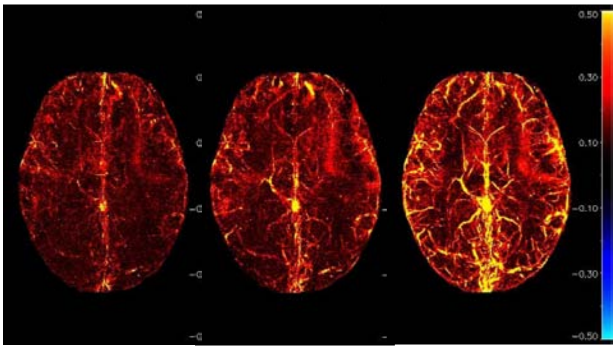

Figure 2: Maps of relative signal change for 0% vs. 1.67%CO_2 (left), 0% vs. 3.33%CO_2 (middle) and 0% vs. 5%CO_2 (right). The relative change of the signal intensity increases with increasing CO_2-concentration. By the CO_2-concentration of 5% signal changes beyond 50% can occur in some venous vessels.

CO2-concentration	Relative signal change	P-Value of t-test
0% vs. 1.67%	+7%	4.4E-5
0% vs. 3.33%	+14%	2.1E-7
0% vs. 5%	+37%	5.9E-10
1.67% vs. 3.33%	+7%	2.1E-6
3.33% vs. 5%	+18%	5.9E-8

Table 1: Relative signal changes averaged over all ROIs containing a venous vessel.

Results: With increasing CO_2-concentration the contrast in susceptibility weighted images decreases (Fig.1). Mean relative signal changes of cerebral veins increase in comparison to pure oxygen (Figs. 2,3). The significance level also increases with ascending CO_2-concentration (Tab.1). Several venous vessels with a twofold signal increase were observed, but no significant signal changes were observed in the segmented grey and white matter, just as the mean signal changes in the ventricles ($p>0.14$), which served as null hypothesis.

The relative signal changes in the venous vessels were significant at all concentrations of CO_2. Even the signal changes between the discrete concentrations were statistically significant. However, the boxplot (Fig. 3) shows that the distribution of signal changes at the concentration of 3.33% CO_2 is the most symmetric and strait one compared to 1.67% and 5% CO_2. The distribution at 5% CO2 is very unsymmetrical, owing to severe motion artefacts due to strong breathing, which occur with higher CO2-concentrations. Besides, the concentration of 1.67% CO_2 showed also significant values, but the mean relative signal changes were too small to draw certain conclusions.

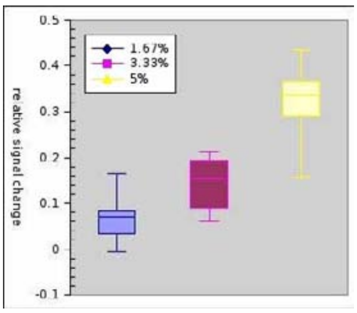

Figure 3:
Boxplot for visualisation of the distribution of signal changes. The rising median values correlate with the increase of CO_2-content. However, the increasing variance of the distributions indicates a stronger interference with motion artefacts at 5% CO_2.

Conclusion: A decrease of CO2 from 5% to 3.33% constitutes a good compromise between sufficient signal changes at tolerable motion artefacts. All volunteers reported reduced discomfort at 3.33% CO_2 compared to 5% CO2. Therefore, a reduced CO_2-content can be recommended for further investigations of tissue and vascular vitality.

References: [1] Taylor, N.J., et.al., J Magn Reson Imaging, 2001, 14(2): 156-163. [1] Hoogsteen, I.J., et al., Int J Radiat Oncol Biol Phys. 2006, 64(1):83-89. [2] Rauscher A, et al. MRM, 2005, 54(1):87-95. [3] Reichenbach JR, Haacke EM, NMR Biomed, 2001, 14(7-8):453-467. [4] Powell ME, et al., Radiother Oncol., 1999, 50(2): 167-171.
[5] Woods, R.P., J Comput Assist Tomogr. 1998, 22(1):153-165.