combined sequence for simultaneous measurement of BOLD contrast and perfusion changes caused by hyperoxia

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Introduction

Simultaneous imaging of blood oxygenation level-dependent (BOLD) contrast and cerebral blood flow (CBF) is interesting for several applications as functional imaging and tumor staging. MRI based arterial spin labeling (ASL) is a noninvasive technique for perfusion imaging. Pulsed ASL (PASL) has the useful property to obtain BOLD-images beside the perfusion-images, when in-plane presaturation is used [1]. The average of temporally adjacent tag and control images can be used for BOLD-signal, whereas the difference between tag and control images gives the perfusion signal. However using this property requires compromises referring to echo time (T_E) and repetition time (T_R) between the optimum for the BOLD-contrast and the ASL-signal. An alternative technique is to use a second echo with longer T_E for the BOLD-images [2]. The only way to separate perfusion and BOLD-contrast completely is to use a combined sequence, which alternately acquires T_2^*-weighted and CBF-sensitive images as it was used in [3] for functional imaging. To investigate the BOLD-signal and CBF-changes in response to breathing gases with different oxygen content the combined sequence is the best alternative, because it is important to have a short T_E for optimisation of the signal to noise ratio (SNR) and to minimize the BOLD contamination of the perfusion signal. On the other hand for the BOLD-images the contrast has to be optimized (longer T_E) and T_1-weighting has to be minimized. We developed a new sequence for an alternating acquisition of BOLD- and CBF-sensitive images and tested it by switching between periods of air and 100%-O_2 breathing.

Methods

Based on a work-in-progress PASL sequence (Siemens Medical Solutions, Erlangen, Germany) the combined sequence was developed. For the CBF-sensitive images the QUIPSS II technique is applied, using PICORE for tagging [4][1]. This sequence was extended by inserting previous to each tag and each control image an T_2^*-weighted image. Since the perfusion-images are calculated by subtraction of control and tag images, it is important to have identical preconditions. T_E and T_R can be chosen separately for T_2^*-weighted and tag/control images. The motion correction of the original PASL-sequence had to be adjusted to the new situation. All imaging is performed using single shot gradient echo EPI with a 64x64 matrix. The new sequence has been implemented on a 1.5 Tesla Sonata scanner (Siemens Medical Solutions, Erlangen, Germany). Two healthy subjects (one female 39 years old and one male 32 years old) were studied. The following parameters were used: 6 slices with d = 7mm and 2mm distance, FOV = 220mm, matrix = 64x64, 6/8 partial Fourier; BOLD: T_E = 65ms, T_R = 3660ms; PASL: T_E = 11ms, T_R = 1620ms, gap between tagging region and first slice = 11mm, TI_1 = 700ms, TI_2 = 1300ms. The breathing paradigma was: air (1,5-3.5min) – 100% O_2 (≈ 4min) – air (5-7min) – 100% O_2 (≈ 8min) – air (3,5min).

Results

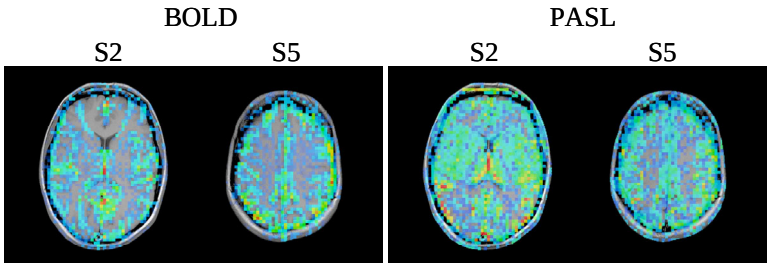

Figure 1: Overlay of the BOLD-map and PASL-map in color onto the anatomical images for two slices of one subject.

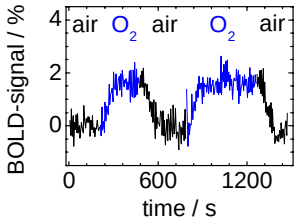

Figure 2: Typical course of the BOLD-signal (median over one slice) changing between breathing air and 100% O_2 .

Figure 1 shows the overlay of the BOLD-map and the PASL-map in color onto the anatomical T_1-weighted images for two slices of one subject. Since the PASL-signal comes from small arteries, the capillary system and tissue, it is more distributed than the BOLD-signal, which derives from venous vessels and nearest surrounding area. Changing from air to 100% oxygen the BOLD-Signal increases because of the higher content of oxygenated hemoglobin, which is not paramagnetic in contrast to desoxygenated hemoglobin. A typical course of the BOLD-Signal is shown in Figure 2. The average BOLD-signal increase observed was (1,6 ± 0.5)%. The PASL-signal decreases changing from air to 100% oxygen. The average signal decrease observed was (35 ± 18) %. This is a combined effect of hyperoxia and hypocapnia induced cerebral vasoconstriction [5].

Discussion

The observed increase of the BOLD-signal of 1.6% is comparable to results reported by Losert et al. [6] (basal ganglia 1.7%, cortical gray matter 3.4%, white matter 0.8%). The observed decrease of 35% of the PASL-Signal fits to the result of 33%, obtained by Floyd et al.[5] with continuous ASL. However the decrease is larger than the results of 13-27%, measured with different methods and reported previously [5]. A possible explanation could be the dependence of T_1 in arterial blood on the concentration of dissolved oxygen. This influence has to be determined further on.
In conclusion, a new combined sequence, which alternately acquires T_2^*-weighted and CBF-sensitive images has been successfully developed. The BOLD- and PASL-signal changes obtained by breathing alternating air and 100% oxygen are comparable to previous reported results.

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