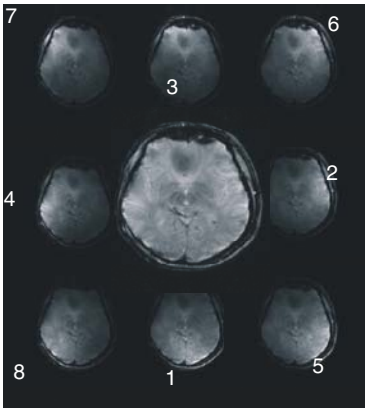
MR-Encephalography: 'Imaging' Without Gradients Using Multichannel Receiver Coils: Applications to Physiological Measurements

J. K. Hennig[1], K. Zhong[1], O. Speck[1]

[1]Diagnostic Radiology - Medical Physics, University Hospital, Freiburg, Germany

Introduction: Parallel imaging has led to tremendous improvement in imaging speed. By use of multiple receiver coils acceleration factors in the order of 2-4 can be achieved in each dimension of a nDFT-experiment. Further acceleration is possible applying constraint reconstruction techniques by introducing prior knowledge into the image reconstruction. The purpose of this paper is to explore the ultimate limits of this approach by acquiring images without spatial encoding gradients using coil sensitivities alone (OVOC = one-voxel-one-coil-imaging) and reconstructing images from a previously acquired template image using the continuosly acquired coil signals as weighting factors for parallel reconstruction (1). The concept is tested to monitor global physiological effects in the brain induced by breathing and ECG by a 8-channel MR-encephalography(MREG).setup using the available equipment on our scanner.



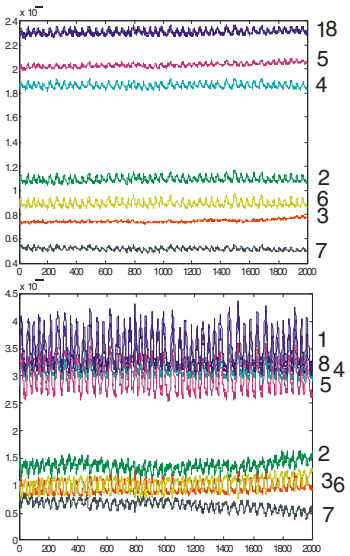


Fig.1 Single coil images (top) and combined reference image. **top right:** total signal amplitude M_Int in the 8 coil elements along time. **bottom right:** on-resonance amplitude C_Int.

Methods: Experiments have been performed on a 3T scanner (Magnetom Trio, Siemens, Erlangen) using the standard 8 channel head coil. For data acquisition a FLASH-sequence has been used, where all gradients could be selectively switched off. In the standard experiment the slice selection gradient was left on and the steady state signal without spatial encoding was collected separately for each coil element. TR of the experiments was varied between 10 and 100 ms. A template image (256x256) was acquired using identical parameters, but with all imaging gradients on. OVOC-experiments were performed in resting state by periodic data acquisition over 1-6 minutes (N=4 subjects). Image reconstruction was performed as follows: From the measured signals the integral M_Int over the magnitude of the signals (reflecting the total signal) was calculated as well as C_Int, the magnitude over the integral which reflects the on-resonance intensity. Using these values as scaling values for each coil, images were reconstructed from the template for each timepoint.

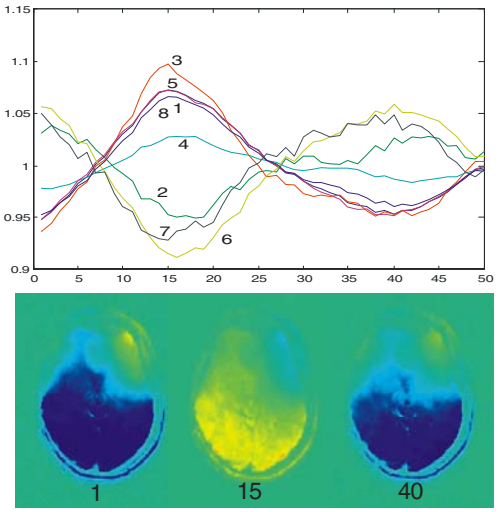


Fig.2 On resonance amplitudes with retrospective averaging over the breathing cycle (top). Difference images at various time points (1 time point = 100 ms), (bottom).

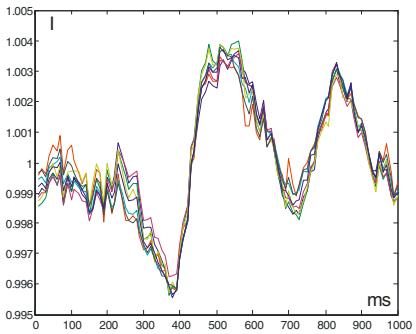


Fig.3 Total signal amplitude with retrospective averaging over the ECG cycle (top).

Results: Experiments showed qualitative similar but interindividually variable signal behavior. Retrospective synchronization similar to the RETROICOR method (2) has been applied to study the correlation of the observed signal fluctuations to breathing and the ECG-cycle. **Breathing effects** Fig. 1 shows results of OVOC with TR of 100 ms. Quasi-periodic fluctuations with a period length of 4.8-5.7 s corresponding to breathing motion are observed in M_Int as well as in C_ Int. This indicates that breathing affects both the amplitude as well as the phase of the signal. Fig.2 shows the signals from the different coil elements after adaptive averaging over the breathing cycle. It is clearly demonstrated, that breathing effects are antiphasic in different coil elements reflecting spatially variable inhomogeneities as demonstrated by the difference images at different time frames in the breathing cycle. **ECG-related effects:**. Fig.3 shows results from an experiment with TR=10 ms and adaptive retraospective averaging to the ECG-cycle (pulse rate varied between 58 and 67 1/s). Contrary to the slower breathing effects, the ECG-related signal modulations are highly coherent in all coils indicating a global variation in the signal probably due to arterial inflow.

Discussion: The very high amplitude of OVOC-signals makes it an ideal tool to study signal variations of effects, which have a spatial variance comparable to the sensitive volume of the coil elements. As shown in Fig.3, even signal changes < 0.5 % can be reliably detected. For the setup using a standard head coil our results demonstrate, that OVOC can be used as a fastnavigator to detect physiological signal variations. The exact signal pattern and amplitude of breathing induced effects is variable between individuals. The results in all subjects clearly indicate, however, that breathing effects are spatially variable and thus can not be accounted for by a global correction term alone.

The global invariance of the ECG-related effect is most probably due to the large sensitive volumes of the coil. With smaller coils it may be possible to use MREG to monitor local arterial pulsatility. The ultimate goal will be to use MREG to study neuronal activity by using very large arrays (>100) of small coils suitable to just reach the cortex. This may allow for true neuronal MREG in a way similar to EEG, but without the inherent localization problems of electrophysiological measurements. The maximum imaging speed for OVOC is limited only by the sampling bandwidth, so framerates of > 1 MHz can be achieved. In practice there is no known MR-sensitive physiological effect occurring at such speed, so it may be advantageous to use several time points to introduce some additional spatial encoding into the signal by appropriate gradients.

References: [1] Hennig J. Mansfield lecture, ISMRM Miami 2005 [2] Glover GH, Li TQ, Ress D. Magn Reson Med. 2000 Jul;44(1):162-7.