Restoration of EEG recorded during functional EPI

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Introduction:

The main application of Electroencephalography (EEG) in MRI is to start functional imaging (fMRI) after an event detected in the EEG. Because the onset of the BOLD contrast is delayed relative to the event in the EEG (2-3 s) and stays active for up to 10 s, it becomes possible to image brain activity that has already been detected on the EEG before. The most promising application of EEG-triggered fMRI is on interictal epileptic activity in cortical brain areas as a noninvasive technique to define epileptic foci (1-3). It has already been shown that EEG recordings in the MR are possible without loss of MR image quality (4,5). In the high static magnetic field, ECG-synchronous artifacts in the EEG were observed and a solution to subtract these artifacts was presented (6,7). However, during all the time of MR data acquisition, the EEG was always completely covered by interference (2-5, 7) and there was no solution so far to restore the EEG. During functional imaging of the baseline, unwanted events must be detectable in the EEG to guarantee the quality of a functional study. So far, the influence of unwanted EEG events on functional imaging could only be excluded if the time of imaging was limited to about three seconds. Then the influence of unwanted EEG events could be excluded by the delay of the BOLD contrast. With a possibility to detect EEG events also during imaging, longer scans with higher resolution can be performed during all the time when the BOLD contrast is enhanced after an event in the EEG (up to 10 s).

Material and methods:

All measurements were performed on a 1.5 T Magnetom Vision whole body scanner (Siemens, Erlangen, Germany), equipped with an EPI booster at a rise time of 300 µs. A circular polarized head coil was used. The commercial EEG amplifier ('EMR' by Schwarzer GmbH, Munich, Germany) is a certified medical product. It was specifically designed for operation in a MR system and was developed in cooperation with our institute (6). We examined the influence of an EPI sequence on EEG recordings since this sequence has been successfully used for functional studies in our institute. The EPI sequence had a repetition time of 1.68 ms, an echo time of 64 ms, a flip angle of 90° degree, a matrix of 64 * 128 and a 6/8 field-of-view of 280 mm. Ten slices of 5mm thickness were measured and the measurements were repeated 10 times. The frequencies induced in an EEG by the EPI sequence were analyzed and compared with the timing of the sequence. The EEG of three patients (2 female, aged 41 ± 5) suffering from epilepsy with over 200 interictal spikes per hour was recorded during the EPI sequence. These patients were on anti-epileptic medication and seizure-free for the last 3 months.

Results:

Interfering frequencies in the EEG corresponded to different repetition times (rt) of loop structures of the EPI-sequence. All interfering frequencies in the EEG were multiples of 1/rt . The switched magnetic gradient fields contributed most to these interfering frequencies. To restore the EEG in the time domain a high and a low pass filter besides the frequency window of the EEG (0.5 to 40 Hz) was applied and within the frequency window of the EEG several band stop filters at the frequencies produced by the loop structure of the sequence were applied. The EEG was also restored in the frequency domain by eliminating interfering frequencies in the fast fourier transform (FFT) of the EEG. Interfering frequencies could also be automatically detected by comparing several EEG spectra off scanning with the affected EEG spectrum during the scan. The complex values of the FFT at the interfered frequencies were set to zero. After retransformation epileptic spikes in the EEG became clearly detectable. Fig. 1 shows 18 channels of EEG of a epileptic patient recorded during EPI. No EEG can be seen under the interfering frequencies. Fig. 2 shows the same EEG after elimination of interfering frequencies in the FFT of the EEG and an epileptic spike in the left temporo-parietal brain area can be detected. The same frequencies that were discarded from the interfered EEG were also discarded from an unaffected EEG. The EEG stayed visually unchanged and this is the proof that the EEG quality is not affected by the processing.

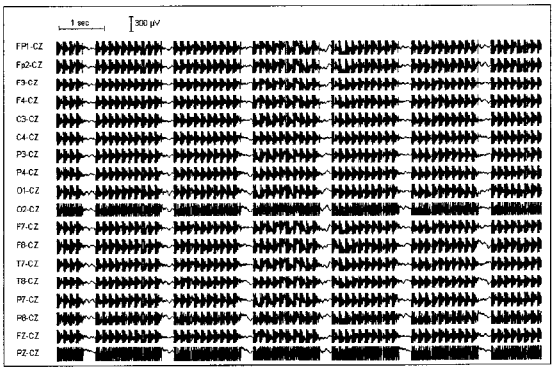

Fig. 1: Interfered EEG during EPI.

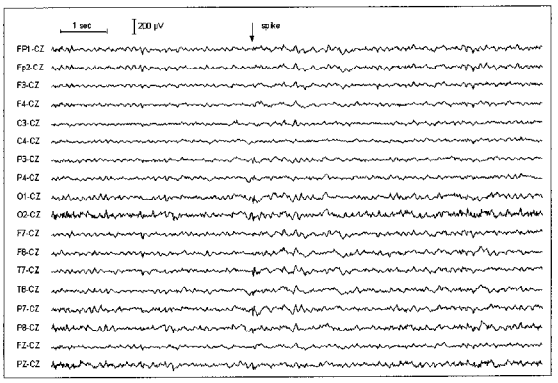

Fig. 2: Same EEG after processing.

Discussion:

Other methods have already been presented to restore electrophysiological signals recorded during MRI, but these were used to restore signals of much higher amplitudes and therefore of much higher signal to noise ratios, such as the ECG (8). Never before an EEG recorded during MRI has been restored. We could show that the EEG quality is not affected by the processing. All demonstrated techniques can also be applied to other electrophysiological recordings performed in MRI, for example EMG, ECG or other signals recorded in the MR environment.

References:

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