Development of a MR-compatible cardiotocograph for the non-invasive assessment of the birth process via MRI.

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Introduction: A cardiotocograph (CTG) is an instrument, which records the fetal heartbeat (cardio-) and the uterine contractions (-toco-) during pregnancy and birth. Magnetic resonance imaging (MRI) allows the real time study of fetal descent stations and maternal pelvic changes [1]. For a non-invasive and MR-safe monitoring of the birth processes we developed an MR-compatible CTG. Therefore, the induced voltages during MR-imaging [2-3], which are superimposing the CTG-data, had to be minimized. In this study we investigated the influence of MR-disturbances generated by spoiled and balanced gradient-echo sequences. Based on the findings, an MR-noise-filter was developed and analyzed.

Figure 1: *Panorama open high-field MRI. A pregnant woman with an ultrasound- and toco-transducer is shown. Next to the MR-scanner was a MR-compatible in room monitor displaying the data of the fetal-monitor.*

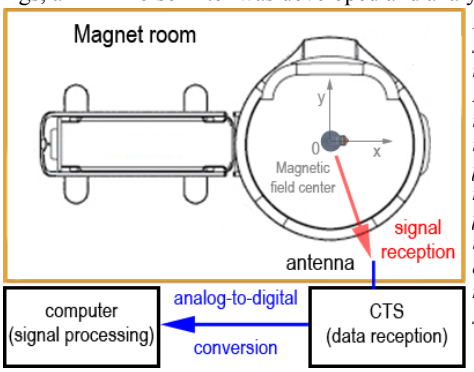

Figure 2: *Experimental setup: the CTG transducer inside the MR-room transmitted the data wirelessly to the base station positioned in the control room. The CTG data is processed and transferred to an MR-compatible in room monitor at the MR-scanner.*

Material and Methods: All measurements were performed in an 1.0 T open MRI (Panorama, Philips, Netherlands). The experimental setup consisted of a wireless fetal transducer system (Avalon CTS, Philips), an analog-to-digital converter and a signal processor. The transducer monitored the fetal heart data via doppler-ultrasound. Uterine contractions were measured by a pressure transducer (figure 2). First, the influence of the repetition time (TR) and the position of the transducer within the MR-scanner on the induced voltage was analyzed. The induced interering frequencies were removed by a comb filter wich was adjusted to the TR-depending noise (figure 3). Additionally, a low pass filter was applied.

Results: The MRI had only a minor influence on the tocograph and no further post processing was necessary. However, the disturbing signals induced in the cardiograph interfered considerably with the cardiac signal. The induced voltage was caused both by the excitation pulses and the switching imaging gradients. The amplitude of the induced voltages increased with increasing distance of the transducer from the center of the magnet. Thereby, the MR-noise was primarily dependent on TR. The frequencies of the MR-noise occurred with n/ TR (s) (for n= ±1, ±2,…). Thereby, the frequency range of MR-noise is wider than the frequency range of the fetal ultrasound data. Thus, low pass filtering already reduced MR-noise without decreasing the fetal signal. Applying the described filter methods reduced the MR-induced noise and a sufficient monitoring of the fetal heart rate was feasible (figure 4).

Conclusions: CTG with additional MR-imaging is feasible using a TR-dependend frequency comb filter. An additional low-pass increases the filter efficiency.

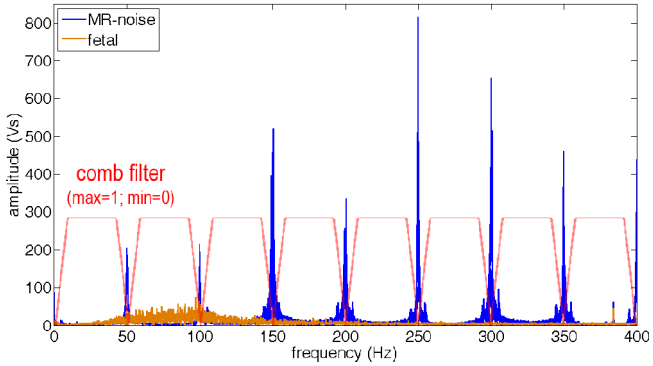

Figure 3: *CTG-data (ultrasound) in the frequency domain. The main frequencies of fetal ultrasound data are located in the range of 20 to 200 Hz (orange line). The frequency range of MR-noise goes up to 1000 Hz (blue line). The adjusted comb filter is marked with the red line. The MR-noise was generated by a gradient-echo sequence (TR=20 ms, TE=5 ms, flip angle= 60°).*

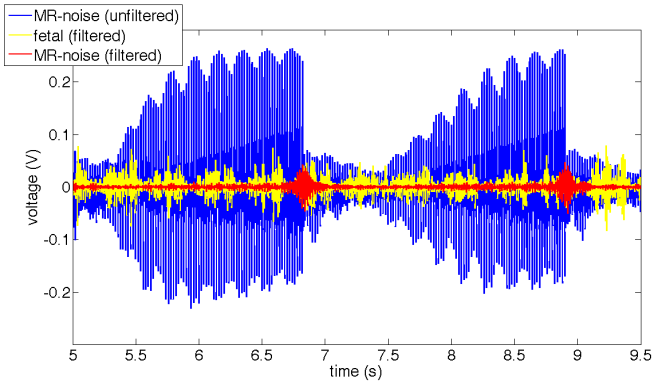

Figure 4: *Excerpt from the data shown figure 3 in the time domain. The blue line represents the unfiltered CTG-data (ultrasound). Using the comb filter and a low-pass filter (cut-off frequency 210 Hz) the fetal heart rate can be determined sufficiently (yellow line). Due to leakage, some noise remains at discontinuities of the initial signal (red).*

References:
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