An Alternative Concept of Non-sequence-interfering Patient Respiration Monitoring

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Introduction

Patient motion is still challenging in MRI, especially in the abdominal region. The use of advanced motion artifact reduction techniques can improve diagnostic image quality. Motion sensing and correction approaches have been described to cope with this problem. However, e.g. navigators [1] influence the steady state of SSFP sequences and are, therefore, not inherently compatible with this technique. Recently, a new principle [2] was proposed for the detection of respiratory motion by changes of coil properties induced by patient motion.

This paper describes the application of this alternative concept for steady state imaging, using a simple retrospective gating approach. Motion information is obtained in real-time. The method is compatible with almost any pulse sequence or k-space trajectory. It is also an advantage that no extra patient preparation is necessary to achieve this kind of motion monitoring.

Methods

Patient motion, e.g. due to respiration, influences the RF coil properties. The change in loading of an RF coil leads to a detectable amplitude change. For the experiments, a whole body 3T MRI system (Achieva, Philips Medical Systems, Netherlands), equipped with eight parallel RF transmit channels [3], was used. A pick-up coil (PUC) monitoring approach was included in the setup to measure the complex currents of each of the eight RF transmit elements of the multi-channel body coil (MBC) [4]. The PUCs are used for detecting potential unsafe system operation [5] as well as for system calibration purposes [6]. However, the same information can further be used to detect respiratory motion. During MRI imaging experiments, the transmit currents in the RF coil elements are sampled during the RF pulses (see Fig. 1).

To demonstrate the feasibility, a Cartesian SSFP sequence was applied (TR=4.4 ms, TE=2.2, α=55°, matrix=320², FOV=320mm). For retrospective gating, an oversampling factor of 10 was chosen resulting in a total scan duration of 14.1sec., covering a number of respiratory cycles. For increased SNR, a six element SENSE cardiac coil was used for signal reception. Written informed consent was obtained from all volunteers involved in this study. The RF pulses were sampled simultaneously via the eight pick-up coils with a temporal resolution of 3.2µs. The information about the amplitude change was extracted from the monitored PUC signals, averaged over each RF pulse, and the best signal was used to determine the respiration state.

Each of the measured profiles was assigned to the appropriate breathing state using a predefined margin of 26% around the end expiration state as shown in Fig. 2. The margin was kept constant, but could be adapted for each breathing interval.

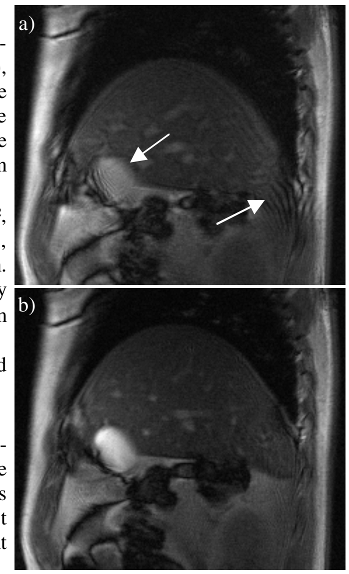

Fig. 4:
a) One example image of the 10 images acquired consecutively during free breathing (arrows indicate regions with artifacts due to motion).
b) The reconstructed image based on the selected profiles of the retrospective gating algorithm.

Results and Discussion

Examples of the respiration signals of four different volunteers are shown in Fig. 3. The maximum obtained amplitude differences were in the range of ± 1.6%. In contrast to [2], where the phase was used for the determination of the respiration state, the amplitude turned out to be more robust, in particular for small flip angles. Even though coupling of the coil elements was present as well as coupling of the PUCs with other coil elements, these contributions were rather constant and resulted in almost no quality decrease of the detected respiration signals. The method was not compromised by different phased array coils present in the magnet and showed reliable motion detection down to transmission flip angels of 1°.

One image acquired during free breathing is shown in Fig. 4a), and artifacts induced by bulk motion are clearly visible. The retrospectively gated image showed significantly less artifacts (Fig. 4b)). Even though the temporal resolution depends on the repetition time TR, this is not limiting the applicability of this concept, because low flip angle dummy RF pulses could be used for sequences with very long TR's.

Depending on the location of the coil elements in the MBC, the signal amplitudes varied considerably. Consequently, signals of PUCs that primarily contributed noise due to their location (e.g. below the patient) were, therefore, omitted. Weighted superposition, including Tx coil sensitivity information, could improve the spatial localization of the motion information. The method offers a continuous monitoring, is imperceptible for the patient and does not require extra attachment of sensors. Furthermore, the scans are not influenced by the method with respect to timing or scan duration and do not influence or disturb the steady state. The respiration state can be determined in real-time from the acquired data. The motion information thus obtainable can be used for real-time triggering or gating, and potentially, for prospective/retrospective motion correction.

Conclusion

The application of this alternative respiration monitoring concept was demonstrated successfully. This approach has the advantage of not interacting with (e.g. steady state) imaging sequences, and is invisible for the patient. In addition, a very high temporal resolution (e.g. sub-millisecond) of the motion information can be achieved in real-time (depending on the length of TR). Consequently, this approach is an interesting alternative to existing techniques.

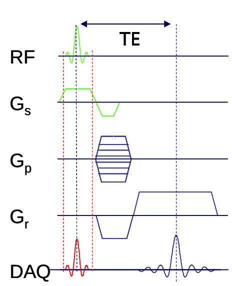

Fig. 1: Principle of PUC sampling during RF pulse transmission. First, the RF pulse is sampled (in red), then the MR response (in blue).

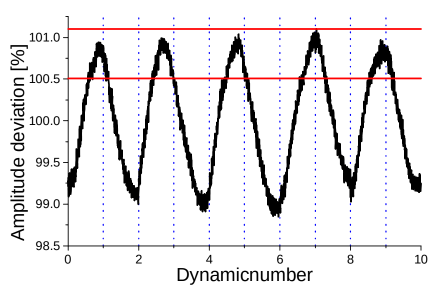

Fig. 2: Extracted sensor signals with a margin of 26% around the end-of-expiration state were used for the selection of the profiles, from which the motion-reduced image was reconstructed.

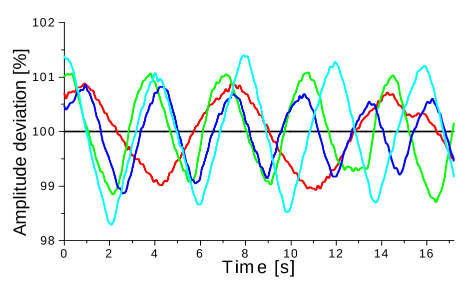

Fig. 3: Amplitude changes during continuous breathing of four volunteers, monitored with the PUCs. The mean value of each individual signal was set to be 100% for better comparison.

References

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