An Alternative Concept of Selfnavigation for Patient Respiration Monitoring

I. Graesslin[1], D. Glaesel[1], P. Börnert[1], H. Dingemans[2], G. Mens[2], and P. Harvey[2]
[1]Philips Research Europe, Hamburg, Germany, [2]Philips Medical Systems, Best, Netherlands

Introduction

Patient motion still represents a challenge in MRI, especially in abdominal MR. Diagnostic image quality can benefit from advanced motion artifact reduction techniques. Mechanical or electrical sensors [1] have to be attached to the patient, add complexity and do not always work reliably. Another approach of detect motion in the use of multiple navigators [2,3], which estimate the respiration state directly from the position of the diaphragm. This is more accurate than electrical sensors, but requires planning and may prolong the scan time. Recently, image-based or self-navigated techniques have been presented [4,5], in which the respiration state is extracted from the measured data. This paper describes an alternative concept of self-navigated respiration monitoring that provides the respiration information in real-time. It is compatible with almost any pulse sequence or k-space trajectory and does not require additional RF pulses or physiology monitoring equipment. Furthermore, an extra preparation of the patient is not required for this form of motion monitoring.

Methods

In general, the patient influences the coil properties. Thus, the loading of the RF coil elements changes during respiration, which can in turn be detected as a phase change. For verification of this approach, a whole body 3T MRI system (Achieva, Philips Medical Systems, The Netherlands) was used equipped with eight parallel RF transmission channels [6]. Each of the eight RF transmit elements of the multi-channel body coil (MBC) is equipped with a pick-up coil (PUC) for monitoring the current in each element in order to support SAR monitoring [7] or system adjustment [8]. However, the same information can also be used to detect respiratory motion. In contrast to a conventional MRI system, where signals are acquired after the excitation pulses, here the currents in the coil elements are sampled during the RF pulses as shown in Fig. 1.

In an initial experiment, a sequence of block pulses (0.2ms/pulse) with a repetition time of T_R of 40ms was applied to the different RF transmit elements. The pulses were sampled simultaneously via the eight pickup coils with a temporal resolution of 0.8µs (2ms after averaging for increased SNR). To change the loading, volunteers kept their breath at four different static breathing stages between inspiration and end of expiration. The acquired samples, collected during each block pulse, were filtered and averaged to increase the SNR. In subsequent experiments, volunteers breathed freely, and the information about the phase change was extracted from the monitored RF pulses of the imaging experiment (FFE, T_R/T_E=50/4ms, flip angle: 25°, slice thickness: 15mm, FOV: 400mm, resolution: 1.6mm×1.6mm). For comparison of the obtained pick-up coil results, a respiration belt was used.

Results and Discussion

Signals referring to the four different static breathing stages of one volunteer can be seen in Fig. 2. A maximum phase difference of about 1° was obtained, and the different signals can be well distinguished from one another. Multiple volunteers were scanned. The example of a free breathing volunteer is shown in Fig. 3.

The detected respiration curve has a good correlation with the signal acquired with the respiration belt. A phase change of 0.6° was detected for a diaphragm displacement of 29.6mm (Fig. 4), which results in a phase deviation of about 0.02° per mm diaphragm displacement. The temporal resolution is dependent on the repetition time T_R of the scan. Furthermore, signals of the individual RF transmit coil elements showed different phase variations, depending on the location of the coil elements in the MBC. The coil elements below the patient showed much less signal variation for the different respiration states compared with the ones above the patient. Potentially, a clever superposition of the signals may allow for even better signal localization. It is worth mentioning that a good signal-to-noise (SNR) of the acquired signals is required, as the accuracy of the phase determination decreases with decreasing amplitude values.

The method offers a continuous monitoring, is imperceptible for the patient and does not require extra preparation time for the personnel. Furthermore, the scans are not influenced 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. It turned out that the actual length of the RF pulses only has limited impact on the calculated respiratory position, so that the method works robustly and is expected to work fine for the majority of scan protocols. The motion information thus obtainable can be used for real-time triggering or gating, and potentially, for prospective/retrospective motion correction.

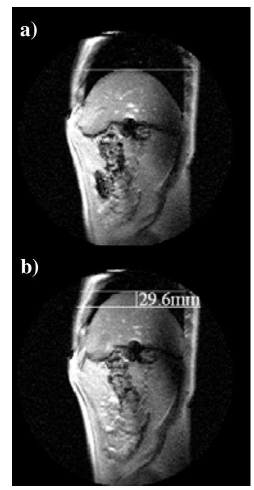

Fig. 4: a) end of expiration and b) inspiration

Conclusion

The basic feasibility of an alternative concept of respiration monitoring was demonstrated. This approach has the advantage of being robust and being invisible for the patient. Furthermore, the respiration information can have very high temporal resolution (e.g. sub-millisecond) and can be determined in real-time. Consequently, this approach of self-navigation is an interesting alternative to existing techniques.

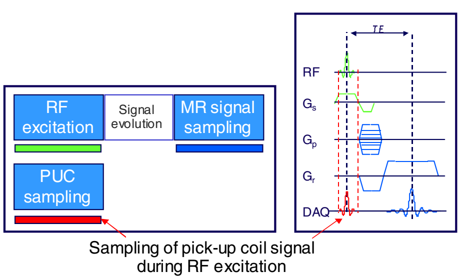

Fig. 1: Principle of sampling the RF signals during RF pulses.

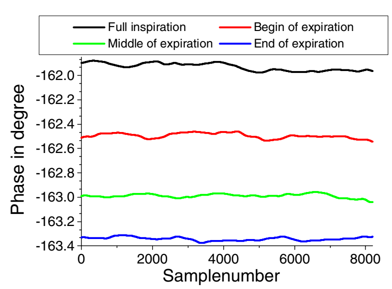

Fig. 2: RF coil phase changes for four different respiration states of a volunteer between inspiration (black) and end of expiration (blue).

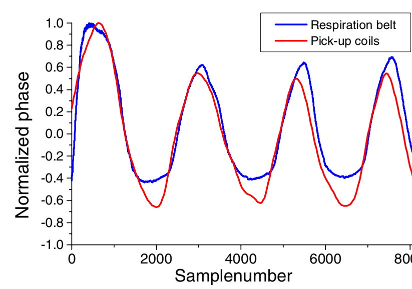

Fig. 3: Phase changes during continuous breathing, monitored with pick-up coils (red) and via the respiration belt (blue).

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