MR compatible sensor for measuring respiratory motion based on acceleration.

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INTRODUCTION:

Patient motion can impair MRI image quality by generating motion artifacts, such as ghosting and blurring. One of the motion elimination techniques, widely used in clinical practice, consists in performing synchronization with heart activity and with respiratory motion [1]. This method requires external or internal sensors capable of providing information highly correlated with internal organ motion.

Respiratory motion is most often monitored with pneumatic belts, which have the advantage of being non-magnetic and relatively inexpensive. However, they suffer from two main shortcomings: signal drifts and leaks in the pneumatic system. Furthermore, resulting respiratory signals reflect an average displacement and thus cannot provide local information.

Therefore, a new MR compatible external sensor has been developed allowing measuring the acceleration of a localized region of the body and providing additional information about patient respiratory motion during MR examination.

MATERIALS AND METHODS:

The external sensor (*Fig.1*) based on acceleration measurements was developed using a SMD technology in order to reduce the surface of the sensor. The direct output from the accelerometer consists in a local acceleration signal, in the direction perpendicular to the sensor. In order to derive displacement information, an integration has to be performed twice. After the first integration, an undesirable constant term appears which has to be eliminated before the second integration.

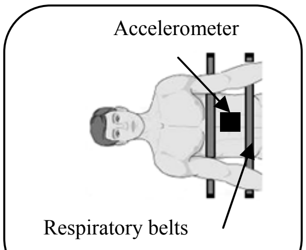

Fig.1: Sensor position

To evaluate the proposed sensor, a test protocol accepted by the ethics committee was implemented. It focused on comparing accelerometer signals to respiratory signals obtained with fast imaging techniques. Four healthy volunteers underwent a chest examination on an 1.5T or on a 3T MR scanner (Signa, GE Medical System Milwaukee, WI). For each subject, several temporal series in a sagittal plane were acquired with an SSFP sequence, with 512x512 spatial resolution and 180ms temporal resolution. The series were acquired in different respiratory modes, including breath-hold, free breathing and deep breathing. Two respiratory belts were used to monitor abdominal and thoracic respiration. These sensors were connected to a custom Maglife (Schiller Medical, France), a device dedicated to physiological monitoring in MRI. The novel sensor was placed on the abdomen between the two respiratory belts. All physiological signals were acquired and recorded using SAEC (Signal Analyzer and Event Controller), a real time signal processing unit comprising a dedicated computer and electronics system [2]. With the purpose of extracting diaphragmatic respiratory motion information directly from the image series, motion detection was performed with a Lucas-Kanade method [3] on every image series. The resulting respiratory signals were extracted from a region of interest (ROI) selected manually in the left upper part of the liver (*Fig.2*).

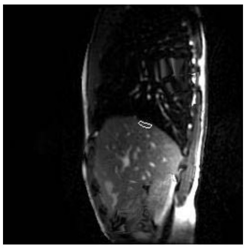

Fig.2: ROI used for displacement extraction

RESULTS:

Fig.3 and *Table 1* illustrate a comparison between internal displacement signals extracted from the image series (*A-P and S-I motions*) and the signals from external sensors, comprising displacement signals estimated by the new sensor (*Acc*) and respiratory signals from the bellows (*Belt*). Correlation coefficient was used as a quantitative measure for comparison. The proposed accelerometer is well correlated to image-based displacement measures. Corresponding correlation coefficient values are similar to those obtained for respiratory belts. It should be noted that there is often a variable delay between real internal motion (estimated from images) and externally measured displacement. Consequently, not accounting for this delay may result in a degraded correlation coefficient even when the displacement information is correct. For subject 4, the correlation between the internal movement and breathing belt is lower than with the accelerometer. Contrary to previous data from volunteers, this sequence was acquired in early inspiration and normal expiration.

	Acc vs A-P motion	Acc vs S-I motion	Belt vs A-P motion	Belt vs S-I motion
Subject 1	0.90	0.89	0.89	0.84
Subject 2	0.94	0.92	0.89	0.87
Subject 3	0.65	0.75	0.71	0.84
Subject 4	0.85	0.87	0.66	0.68

Table 1: Absolute value of correlation coefficient between internal displacement and signals extracted from sensors.

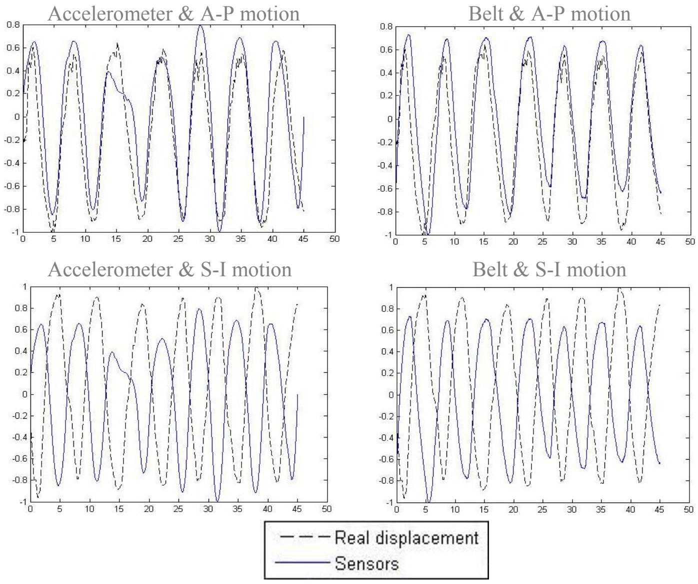

Fig.3: Real displacement (dotted black) compared to accelerometer and respiratory belts (blue) signals.

CONCLUSION:

This work demonstrates the feasibility of measuring respiratory motions using an accelerometer. The proposed sensor allows for local displacement estimation, whereas standard techniques provide only information about an average displacement. Further work will be focused on determining the exact relationship between internal displacement and the one obtained from the accelerometer. The accelerometer seems to be more effective than the belt for quick breaths. The sensor presents also some practical advantages: it is small, easy to position on the patient and less cumbersome than respiratory bellows.

REFERENCES: [1] Ehman et al.,AJR, vol.143, pp.1175-82, (1984); [2] Odille et al., IEEE T Bio-Med Eng April: 54 (4), (2007); [3] Lucas and Kanade, In Proceedings of the International Joint Conference on Artificial Intelligence, pp.674-679, (1981).