MR compatible spirometer

L. Rousselet[1], M. Filipovic[1], S. Jovanovic[1,2], G. Bosser[3], C. Pasquier[4], and J. Felblinger[1]
[1]IADI, Nancy-Université, Nancy, France, [2]U947, Inserm, Nancy, France, [3]Physical Medicine and Rehabilitation, University Hospital of Nancy, Nancy, France, [4]CIC801, INSERM, Nancy, France

Introduction:

MR compatible spirometer is needed for (i) monitoring of anaesthetized patients and (ii) sequence synchronization and/or image reconstruction. Patient motion is likely to induce motion artifacts (ghosting) in image thus reducing its quality during MRI acquisitions. When breath-hold acquisitions are not possible, as for uncooperative children, an alternative technique is proposed, including anesthesia and artificial breath-hold during image acquisition. This technique involves risks. An alternative to this technique for gating is the measurement of inspired or expired volume of air, with or without associated ECG gating. Furthermore, information about exact air flow could be useful for studying cardio-respiratory interactions.
An MR compatible spirometer was integrated on a respiratory mask to have an accurate control of patient's air flow and lung volume. The proposed sensor could be connected to the respirator in order to monitor patients during MRI examination.

Materials and Methods:

The spirometer is composed of three elements: (i) a mask, (ii), a pneumotachographe and (iii) an electronic circuit measuring the differential pressure measurements and developed using an SMD technology reducing the surface of the sensor. Based on the Venturi principle, the pneumotachographe allows for determining the airflow through itself by measuring pressure variation.
To evaluate the proposed sensor, a test protocol was implemented. Its main focus is to perform a comparison of respiratory mask signals and respiratory signals obtained with several standard methods. 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. The series were acquired in different respiratory modes, including breath hold, free breathing and deep breathing. To monitor abdominal and thoracic respiration, two respiratory belts were used. These two sensors were connected to a custom Maglife (Schiller Medical, France), a device dedicated to physiological monitoring in MRI. The developed spirometer was placed over the mouth and the nose (*Fig.1*). 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 [1]. In order to extract diaphragmatic respiratory motion information directly from the image series, motion detection was performed with a Lucas-Kanade method [2] on every image series. The resulting respiratory signals were extracted from a region of interest (ROI) selected manually in the upper part of the liver (*Fig.2*).

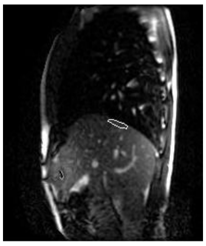

Fig.2: ROI used for displacement extraction

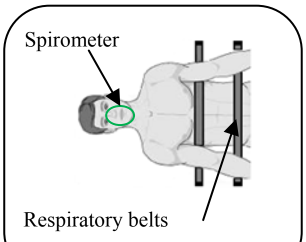

Fig.1: Sensor position

Results:

Fig.3 illustrates a comparison between the internal displacement signals extracted from the images series (*A-P and S-I motions*) and signals from the proposed sensor (*Mask*) or signals from respiratory belt (Belt). The proposed sensor has a good correlation with calculated displacements.
However, it can be noticed that there is a delay between spirometer signals and the other signals which distorts the correlation coefficient. *Table 1* shows, for three subjects, a comparison between signals extracted from the image series and spirometer signals in two cases: (i) without processing and (ii) with a discrepancy correction (*Mask shift*). This time delay is due to the outlying position of the sensor relative to the internal displacement.

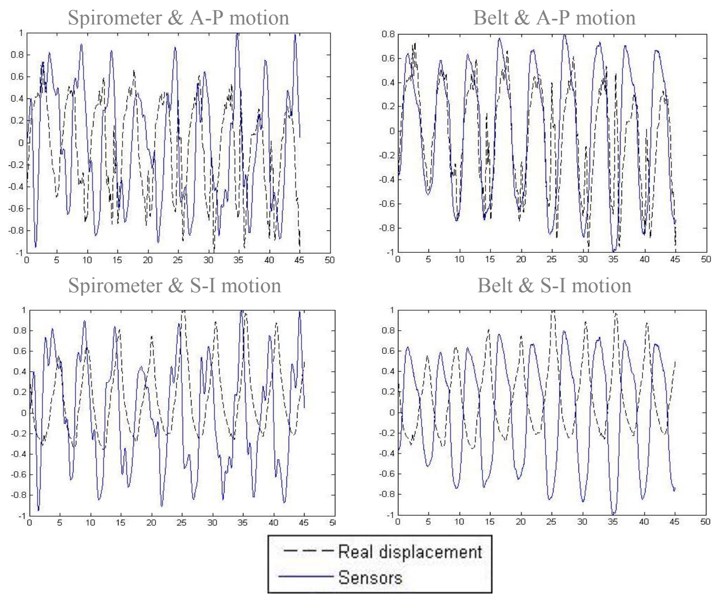

Fig.3: Real displacement (dotted black) compared to proposed sensor and respiratory belt (blue) signals.

Conclusion:

We have shown that the technique based on a dedicated spirometer can be used in an MR environment for patient monitoring and as well to provide information about patient motion. The patient motion information is very useful in image reconstruction phase to cope with undesirable artifacts such as ghosting and blurring. Moreover, the dedicated spirometer presents a benign solution for uncooperative patients not involving any risks to their health compared to commonly used anesthesia technique. Further work will be focused on functional study.

	Mask vs A-P motion	Mask Shift vs A-P motion	Time Delay (s)	Mask vs S-I motion	Mask Shift vs S-I motion	Time Delay (s)
Subject 1	0.72	0.82	0.6	0.72	0.82	0.7
Subject 2	0.10	0.55	1.5	0.45	0.64	0.9
Subject 3	0.15	0.75	1.3	0.19	0.82	1.5

Table 1: Absolute value of correlation coefficient between real displacement and mask signals with and without time delay correction.

References:

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