Simultaneous monitoring of cardiac and respiratory signals using a markerless optical system

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Introduction and purpose: The monitoring of patient cardiac and respiratory signals is necessary in many MR imaging situations. The electrocardiograph signal is often used to track the cardiac cycle; however, this requires the attachment of electrodes and the signal is often corrupted by the scanner RF field and the imaging gradients. An alternative is a finger-mounted pulse oximeter (photoplethysmograph), but this also requires interaction with the subject. Respiratory motion is often measured using an air-filled belt attached to a pressure sensor. The purpose of this work was to investigate the feasibility of obtaining both cardiac and respiratory signals, optically, without physical contact to the subject.

Methods: *Hardware* – An in-bore camera normally used for prospective motion correction [1], was modified for this work. The camera was mounted above the head coil so that it had an unobstructed view of the subject's forehead (Fig. 1a). Unlike in Ref. [1], no marker was used, so images showed only the subject's skin (Fig. 1b).

Data collection – Video data were collected at a rate of 30 fps from a volunteer placed at the isocenter of a GE MR750w scanner. For validation purposes, data from the vendor-supplied pulse oximeter and respiratory belt were also acquired. Data from all three sources were logged for a total of 90 s, comprising three 30 s blocks: (a) no MR imaging, (b) imaging with a 3D FSPGR sequence (c) no MR imaging. Approximate manual synchronization between data streams was achieved by initiating logging simultaneously.

Data processing – Cardiac and respiratory data were computed separately from the same video data (Fig. 2). It is well known that light absorption of the skin varies with the cardiac cycle; therefore, the mean pixel intensity was calculated for each frame as a means to quantify this. This signal was then filtered using an FIR filter with passband between 0.6 Hz and 10 Hz. Respiratory motion was computed by calculating the frame-to-frame image displacement in the z (i.e. head-feet) direction, using the subpixel phase correlation method described in Ref. [2]. Respiratory data were filtered a similar way to cardiac data, except the filter passband was 0.2 Hz to 0.6 Hz. All data streams were scaled to give a mean of 0 and a range of 1 in each case, to allow easy comparison between them.

Results: Fig. 3 shows results for both cardiac (Fig.3, top) and respiratory (Fig. 3, bottom) signals from the subject. A good match to the data from the pulse oximeter and respiratory belt is apparent in each case. The maximum image displacement from the initial position was 16 pixels (approx. 3 mm), indicating that the subject stayed relatively motionless during the experiment.

Discussion: Small in-bore cameras are becoming popular for prospective motion correction [1,3]. This work indicates that the same hardware could be used to acquire cardiac and respiratory data. In some cases, it might be possible to replace the pulse oximeter and respiratory belt, simplifying patient handling.

Although cardiac data can also be obtained from the ballistocardiogram via highly sensitive tracking of head-feet motion of a marker [4, 5], the method presented here using reflected light appears to be more robust and has the advantage of not requiring a marker.

The manual synchronization between video data and the pulse oximeter and respiratory belt data appears adequate for this proof-of-concept study. However, further tests should include more accurate synchronization and trials on a patient population to determine robustness against patient motion.

Conclusion: Simultaneous detection of cardiac and respiratory signals is possible optically, using only light absorption changes and motion information, derived from image registration. This may provide patient handling and MR compatibility advantages over existing methods.

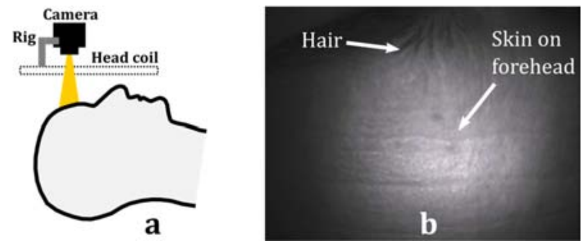

Fig. 1: (a) Camera system mounted on rig above head coil and used to obtain images of the subject. (b) A single frame from the 30 fps video stream showing skin on the subject's forehead.

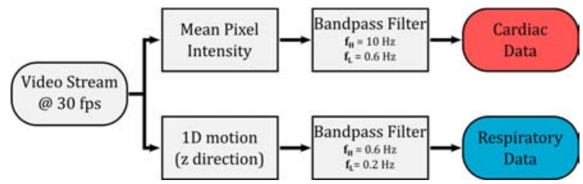

Fig. 2: Processing applied to video data to obtain cardiac and respiratory information.

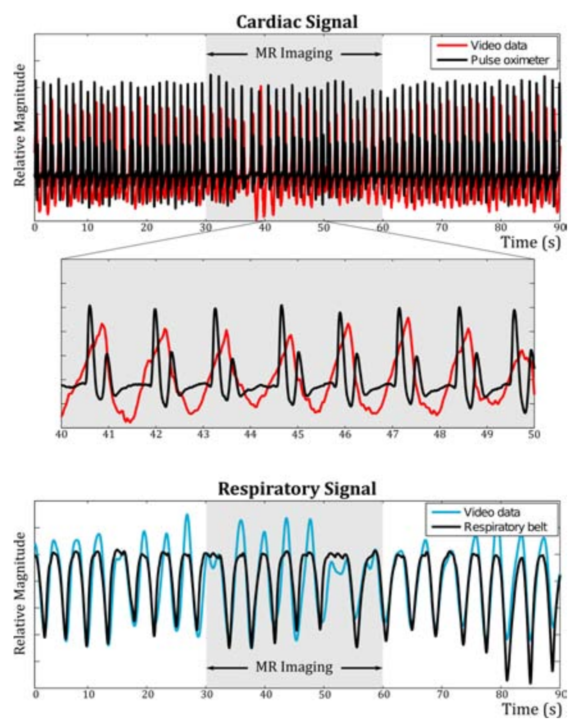

Fig. 3: Extracted cardiac (red curve, top) and respiratory (blue curve, bottom) signals, compared to pulse oximeter and respiratory belt data (black curves), respectively. Simultaneous MR imaging occurred from 30-60 seconds (indicated by grey band).

Acknowledgements: NIH (2R01 EB002711 , 5R01 EB008706, 5R01 EB011654), the Center of Advanced MR Technology at Stanford (P41 RR009784), Lucas Foundation. **References:** [1] Aksoy, et al., MRM 2011;66:366-78. [2] Maclaren, et al. MRI 2008; 26:474-83. [3] Qin et al., MRM 2009;62:924-34. [4] Schulz et al., MAGMA 2012;24:443-53. [5] Maclaren et al., PLoS ONE 2012; 7: e48088.