Quantitative study of motion detection performance of center-of-kspace measurements

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Introduction

In recent years, wireless gating techniques have been explored in MRI as an alternative to conventional cardiac and respiratory triggering methods. An additional acquisition of the center of k-space in every TR has been proposed as a useful source of motion information, be it cardiac [1,2,3], respiratory [4] or both simultaneously [5]. In this abstract, an attempt is made to systematically investigate how well the k-space center signal tracks motion. This is done by computing its correlation with more established motion detection methods such as respiratory bellow and pencil-beam navigator echoes as well as fat selective pencil beam navigators that track cardiac motion directly and exploring its dependence on slice orientation, position and thickness.

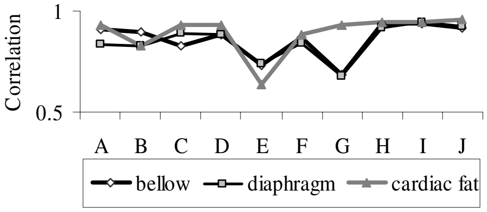

Fig 1. Average correlation of center-of-k-space signal with bellow, diaphragm and cardiac fat waveforms (letters A,B,… indicate different scan locations (see text)

Methods

Experiments were performed on six healthy volunteers using a 1.5T GE Excite MR scanner using an 8-element cardiac coil. *Motion signals.* For each subject, the following signals were recorded: **(1)** Respiratory bellow waveform during each scan **(2)** Diaphragm position as measured by a pencil-beam excitation (3 cm diameter) through the right hemi-diaphragm **(3)** Heart position as measured by a fat selective pencil-beam excitation (9 cm diameter) through the heart (using the cardiac fat navigator method developed in [6] **(4)** k-space center signal as an additional data acquisition every TR [3]

Imaging planes. For each subject, the following scan locations were imaged repeatedly **(A)** Heart short axis (SA) near the cardiac base – 8 mm slice thickness **(B)** SA mid ventricle – 8 mm **(C)** SA near the heart apex – 8 mm **(D)** SA mid ventricle –60 mm **(E)** 4 chamber (4CH) – 8 mm **(F)** 4CH – 60 mm **(G)** Axial through the heart (AX) – 8 mm **(H)** AX – 60 mm **(I)** Axial through the liver (LVR AX) – 8 mm **(J)** LVR AX – 60 mm..

Data processing. For each data pair and image plane, the squared Pearson correlation coefficient r^2 is calculated to measure linear correlation. In the case when more than one waveform was available (real/imaginary part of complex signals or multiple coil elements), the correlation was maximized over all possible combinations. Correlation was further maximized by finding the optimal time delay between waveforms in the case of hysteresis [7].

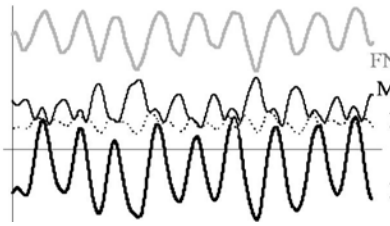

Fig 2. Cardiac fat displacement (Nav) versus real, imaginary and magnitude of center of k-space

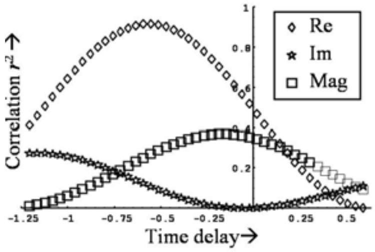

Fig 3. Correlation of cardiac fat displacement with real (Re), imaginary (Im) and magnitude (Mag) for the waveform in Fig as a function of time delay (in sec)

Results And Discussion

➔*Average correlation* between center of k-space and the other motion measurements was good to excellent (Fig 1). Excellent correlation was found for the axial slices through the liver and the thin short axis slices. Although not statistically significant over the small number of subjects, a smaller correlation was found for the thin axial slice through the heart and the thin 4 chamber view.

➔*Complex k-space.* Because the center-of-k-space signal is in general a complex number, it is important to look at variations of both the real and imaginary part in addition to its magnitude. Fig 2. shows a comparison in one subject of an actual cardiac fat displacement waveform and the center-of-k-space signal for a short axis slice. Good correlation is only found with the real part of the signal. Fig 3 shows the correlation of the different parts of the complex signal with the cardiac fat displacements as function of the introduced time shift between signals.

➔*Time delays* Figure 4a) shows the correlation between cardiac fat and diaphragm displacements as a function the time delay introduced in the diaphragm signal. Without this delay the corresponding scatter plot shows a hysteresis loop (Fig 4b) (shown for one subject), which can be closed by selecting the optimal time delay (thereby maximizing linear correlation) (Fig 4c). A scatter plot of this optimal time delay and the corresponding correlation over all planes in all subjects is shown in Fig 5.

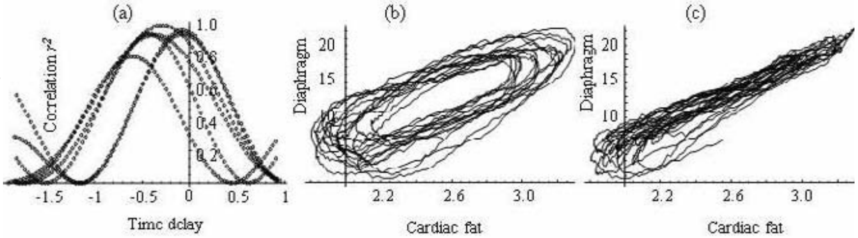

Fig 4.Correlation of diaphragm and cardiac fat displacements (a) Correlation r^2 as a function of imposed time delay between waveforms over all subjects (b) Scatter plot for one subject without shifting (c) Scatter plot in the same subject after shifting the diaphragm waveform over the optimal delay (i.e. the one giving optimal correlation

➔*Imaging planes* High correlations can be obtained in the cardiac fat versus center-of-k-space case (Fig 5a) while the center-of-k-space and bellow signals are not necessarily experiencing the same motion (Fig 5c). This can also be seen in Fig 6. Here, correlation with bellow signal appears to be better with diaphragm position. Its correlation with the center-of-k-space signals is highly scan plane dependent.

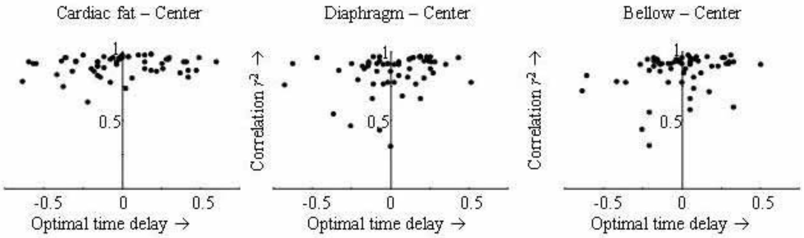

Fig 5. Correlation of center k-space signal with other motion measurements vs optimal time delay corresponding to that correlation. Each point represents one scan plane in one volunteer.

Conclusion Examining the correlation of the center-of-k-space signals with diaphragm and cardiac fat navigators might prove to be useful for calibrating and optimizing respiratory self gating techniques. Motion detection may be excellent for some imaging locations but may fall short for specific orientations because of lower correlation to respiratory motion.

References

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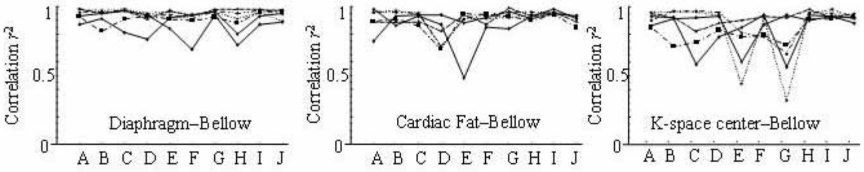

Fig 6. Variation of the correlation of bellow signal with diaphragm , cardiac fat and k-space center.