Physiological Gating System

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Introduction:

The electrocardiogram, ECG, measures the depolarization and repolarization of the heart. This electrical current induced by the heart is generally indicative of the movement of the heart. However, in MR patients with premature atrial and ventricular beats as well as T-swells, which occur in an MR system, the triggering system may read this information as standard heart beats. These anomalous beats, may create artifacts in the MR images. Furthermore, the electrical current does not give an accurate measurement of the onset of diastole. The onset of diastole can be approximated, but with patient variability, it is difficult to provide an accurate measurement. For example, coronaries are small, tortuous and subject to substantial motion. Therefore, the imaging of coronaries must be completed only in the diastolic phase of the cardiac cycle to obtain good image quality. Techniques, such as 3D fatsat SSFP, rely on a delay after the R-wave to determine the optimal point to acquire data. Additionally, simultaneous measurement of cardiac and respiratory data would be useful. A mechanical gating signal, which measures slight vibrations from the body surface can be used to gate an MR system. Since the system does not rely on electrical signal, it will not be affected by the magnetic field. MCG is not meant to replace the ECG but rather to work as a complementary gating device.

Method:

Although this system will work at any field strength, the initial tests were completed on a 1.5T GE LX System. The sensor uses a pair of ultrasound transceivers (Nexsense, Israel) that measures both displacement and acceleration (second derivative) in the heart. Patients setup for displacement triggering, has the patient lie on a pad with the sensor inside it. The acceleration probe is placed on the patient's chest. Notice that there are two signals present in the mechanical gating signal. The initial one is from the onset of systole where the semilunar valves open and the atrioventricular valves close. The second one is at the onset of diastole, which is where the semilunar valves close and the atrioventricular valves open. Either triggering signal can be chosen depending on the need for systolic or diastolic gating. High-Pass and Low-Pass filtering of the signal are used so that only frequencies of the respiratory and cardiac cycles are seen. Figure 1 shows timing of the mechanical gating signal compared with that of the ECG signal and its relationship to data acquisition. For diastolic imaging, the second trigger can be used. If prep pulse are used they can be triggered during systole using the first pulse.

Figure 1 – ECG/ MCG Timing

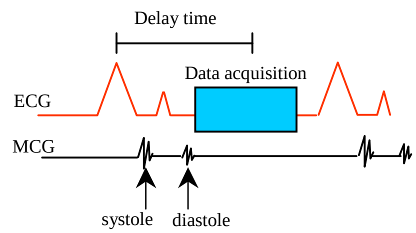
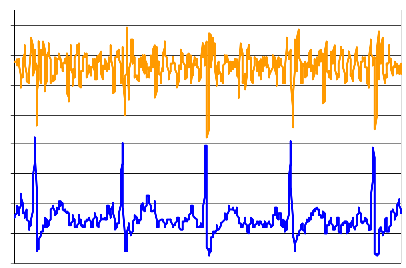


Figure 2- Clinical ECG vs MCG

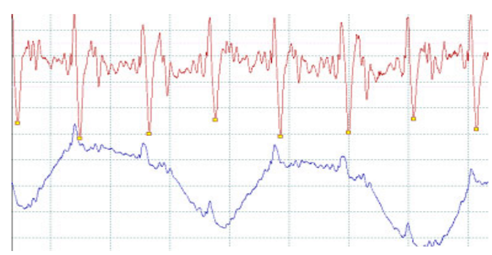


Results/ Discussion:

A comparison between the MCG (orange) in the acceleration mode and ECG (blue) gating on a patient with atrial fibrillation can be seen in figure 2. Although the gating signal is a little bit noisy, the system can still pick out the appropriate triggers for the system. The initial trigger occurs following the R-peak and the second trigger occurs following the T-wave on the ECG. The signal from the gating sensor using displacement mode can be seen in Figure 2. The lower signal (blue signal) is not filtered and therefore includes the respiratory waveform, which can be seen with the cardiac waveform super-imposed on top of it. This signal is then filtered to exam frequencies only in the heartbeat range. The waveform above in red shows the displacement cardiac signal. The very small yellow boxes at the bottom of the signal show the trigger points of the system. This shows that the proper filtering will allow the mechanical signal to produce both the cardiac and the respiratory signal.

Preliminary data shows that we get good quality images from this type of gating method. Figure 4a and 4b show images using the gating system. Both of these images are SSFP 2D images, 224 x224.

Figure 3 – Raw and filtered displacement signal



Conclusions:

Although these are preliminary results to the mechanical gating, initial studies look promising. The most beneficial part of this gating system will be that we can use the diastolic part of the signal to start the data acquisition from. This will improve upon techniques such as the Fat-sat SSFP 3D technique, which rely on imaging in the diastolic region of the heart cycle. Furthermore, used in conjunction with standard ECG gating, on hard to gate patients, this will improve the performance of triggering the system. Also important is the simultaneous acquisition of the respiratory signal, which can be used instead of a bellows system.

Figure 4a –Short Axis

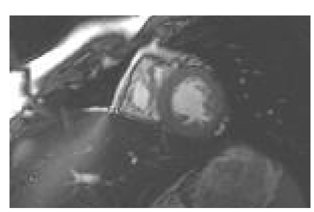


Figure 4B- Long Axis