Real-Time Triggered Single R-R CINE Imaging for Whole Heart Coverage in a Breath Hold

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Introduction:

Ventricular assessment is one of the most important cardiac imaging applications. Traditional evaluation of ventricular function has relied on repeated cardiac-gated acquisitions over multiple cardiac cycles using multiple breathholds for the necessary volumetric dataset. The resulting images frequently suffer from misregistration due to differing breathhold positions and are often of poor quality in patients with an irregular cardiac rhythm. The approach proposed in [1] alleviates misregistration issues by providing whole heart coverage in a single breath-hold, and eliminates the sensitivity to arrhythmias by acquiring the data in real-time (i.e. no cardiac gating). However, the number of acquired images varies from beat-to-beat and hence from location-to-location, and the acquired data is not synchronized to the cardiac cycle. Nayak et al [2] proposed a method that synchronizes real-time imaging to the cardiac cycle, but still produces a variable number of images for each slice.

Building upon this prior work, we propose a new approach that allows real-time, ungated localization of desired slices followed by an immediate switch to a 2D cardiac gated high-resolution CINE mode which acquires one slice per R-R interval and provides full heart coverage in both short and long axis orientations within a single breath-hold. This new "triggered" real-time method alleviates sensitivity to arrhythmia since all data for a given slice is acquired in a single R-R period, it does not suffer misregistration since all slices are acquired in a single breathhold, it allows interactive localization and adjustment of the slices of interest, and it will enable easy display and analysis of the acquired images since the retrospective CINE interpolation produces a fixed number of images for each R-R period.

Methods:

Our new real-time cardiac imaging tool was implemented on a GE 1.5 T Signa Twinspeed system (GE Medical Systems, Milwaukee, WI) with a high performance gradient system achieving a maximum gradient strength of 40mT/m and maximum slew rate of 150mT/m/msec. An 8-element phased-array cardiac coil was used for image acquisition. During a typical study using the new tool, several short axis, two chamber and four chamber views are acquired to provide whole heart coverage. Localization is performed in real-time. Following localization, a single button push instantaneously switches the acquisition to a 2D high-resolution gated CINE mode. All previously localized views are then sequentially acquired. The resulting CINE image loops are automatically saved to a separate series.

Both the real-time and the CINE acquisition modes in our application use a balanced SSFP (FIESTA, Balanced FFE, True-FISP), half-Fourier acquisition with a 50° flip angle, 36-cm FOV, 3.0-ms TR, 1.4-ms TE and 8-mm slice thickness. The CINE acquisition uses ASSET, a parallel imaging approach similar to SENSE [3], with an acceleration factor of 3, and a matrix size of 160x128. The acquired data are retrospectively interpolated to reconstruct 20 phases per location. For each slice, 1R-R interval is spent achieving steady state and 1 R-R interval is used for imaging. The real-time localization mode uses the same acquisition matrix as the CINE acquisition but without using ASSET, resulting in a lower resolution image. The user interface allows the real-time adjustment of slice thickness, flip angle and FOV. Contextual information including center frequency, transmit/receive gains, and shim values is automatically shared between the real-time and CINE acquisitions. After the CINE acquisition is complete, the system immediately returns to the continuous acquisition, reconstruction and display of real-time interactive images.

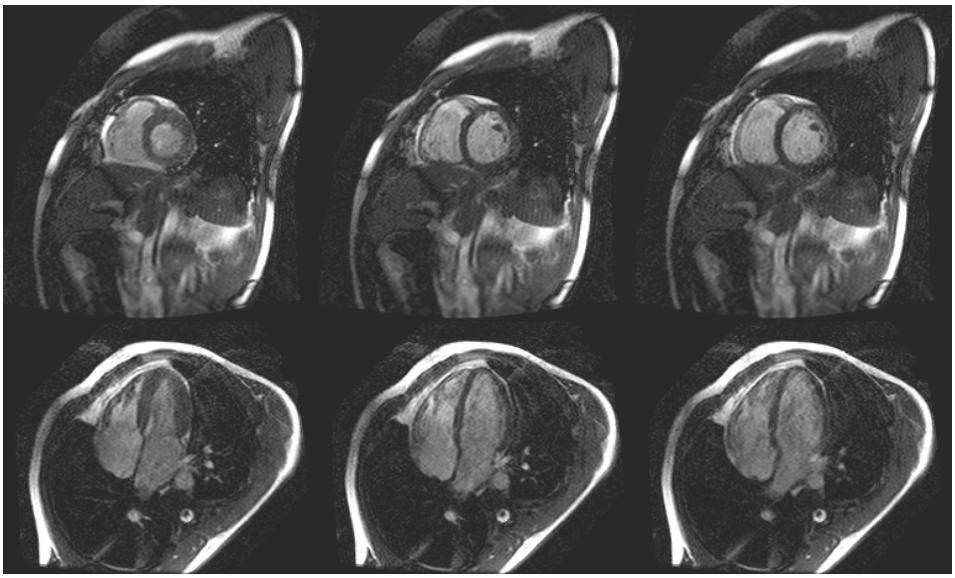

Figure 1. Representative phases of a short and long axis CINE acquisition using our "triggered" real-time tool. TR/TE = 3.0/1.4, 36 cm FOV. The acquisition time for a single image is ~90 ms.

Results:

Figure 1 shows selected phases from CINE short axis and long axis acquisitions on a healthy volunteer acquired using our "triggered" real-time tool. These images are part of a complete cardiac data set that included 5 short axis, a 2 chamber and a 4 chamber view. The whole set was acquired in one 15 second breath-hold. The acquisition time of a single image was ~90 ms. No significant blurring is appreciable in the images. Good contrast can be seen between the myocardium and the chamber blood.

Discussion and Conclusion:

The evaluation of cardiac morphology and function is one of the most important applications of cardiac imaging. Real-time interactive imaging can provide accurate slice placement but can be limited by lower resolution. The combination of a real-time, high frame rate acquisition with a real-time guided high-resolution single breath-hold CINE acquisition overcomes both slice positioning and resolution issues while minimizing the effects of cardiac arrhythmia and misregistration. The acquisition of each slice is completed within a single R-R interval, making it insensitive to arrhythmias, while slice progression is synchronized with the cardiac triggers. Real-time localization also facilitates the prescription of multiple non-parallel slices, enhancing the efficiency of the study. The method can be easily extended to examination of valvular morphology where careful slice selection and higher spatial and temporal resolution are even more essential.

Flexible inter-sequence switching in cardiac MR evaluation has enormous potential to improve the quality, accuracy and efficiency of cardiac magnetic resonance evaluation.

References:

1. Li, B, et al. ISMRM 2003, 380.
2. Nayak, K et al. MRM 49: 188-192, 2003
3. Pruessmann KP, et al. J Magn. Reson. 42, 952-962, 1999