The Use of Biofeedback with mCLAWS to Guide Respiration and Provide Inspiratory and Expiratory Images from a Single Navigator-Gated 3D Coronary MRA Acquisition.

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Introduction: A technique, mCLAWS (1), has previously been presented which allows multiple images to be generated from a single navigator-gated acquisition. It expands on the original CLAWS technique (2), which provides the maximum respiratory efficiency for any respiratory pattern, and enables reconstruction of end-expiratory and end-inspiratory images as well as those in the most efficient 5mm gating window. Respiratory patterns vary enormously between patients. In most (but not all) subjects, the end-expiratory images are of high quality while the end inspiratory images are poorer. This is due to a shorter end inspiratory pause and to a greater degree of variability in the end inspiratory position. The aim of this work is to combine respiratory biofeedback with mCLAWS in order to regularise the breathing pattern and to exploit the ability of the technique to generate end-expiratory and end-inspiratory images from a single acquisition.

Method: A respiratory biofeedback 'game' has been developed to guide the respiration of a subject (Figure 1). The position of an object, in this example a plane, is controlled by the diaphragm position of the subject, as determined by a standard navigator echo. Initially, the subject breathes for several respiratory cycles whilst the expiratory and inspiratory positions are calculated. Targets, in this example hoops, are then placed at the end-inspiratory and end-expiratory positions in order to guide the subject's breathing. A 3D navigator gated balanced steady state free precession (nav-bSSFP) sequence was modified to enable the acquisition of navigator echoes every 100ms prior to the imaging segment in diastole. Only the last navigator was used by the CLAWS algorithm to determine the next data segment to acquire, while the remainder were used to 'fly the plane' smoothly.

Object (plane) controlled by diaphragm position
Desired End-Expiratory Range
Desired End-Inspiratory Range

Figure 1.

Results: Initial results have been very promising, an example is shown in Figure 2. Figure 2a shows the respiratory pattern when no respiratory biofeedback is presented. The end-expiratory position is relatively stable whilst the end-inspiratory position is highly variable. The use of respiratory biofeedback has resulted in stable end-expiratory and end-inspiratory positions, as shown in Figure 2b.
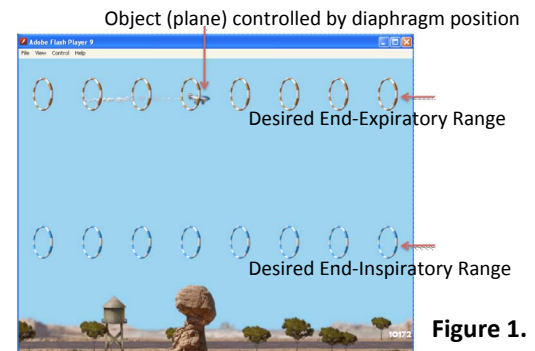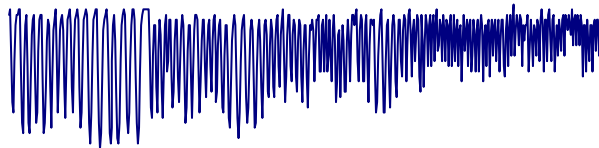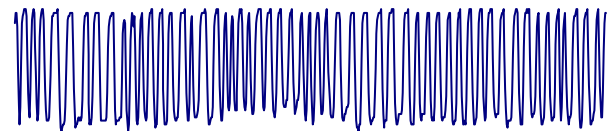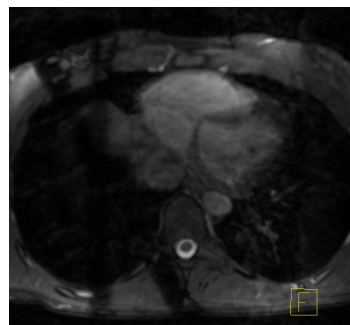

Figure 2.

(a) No biofeedback

(b) With biofeedback

The resulting images are shown in Figure 3 below. With biofeedback, both end-expiratory and end inspiratory images are of good quality (b) whereas without feedback, only the end-expiratory images are good.
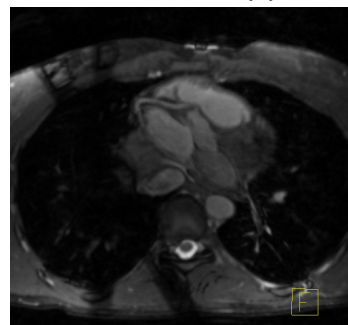
(a) No biofeedback

(b) With biofeedback

End-Expiration   **End-Inspiration**   Figure 3.   **End-Expiration**   **End-Inspiration**

Conclusion: The use of respiratory biofeedback and mCLAWS enables high quality images at multiple respiratory positions to be reconstructed. In this case, biofeedback has been used to guide the expiratory and inspiratory positions. However, since all data is stored, mCLAWS can reconstruct any number of data sets between expiration and inspiration. Biofeedback techniques designed to encourage a uniform respiratory profile could exploit this further. This technique could be useful in applications such as respiratory motion modeling for high resolution coronary artery imaging where accurate models could allow acquisitions with an increased navigator acceptance window and improved respiratory efficiency.

[1] Jhooti et al. Are we Reconstructing the Best Images using navigator-gated 3D coronary MRA? Multiple-Image reconstruction using CLAWS. ISMRM Seventeenth Annual Meeting, Hawaii, 2009
[2] Jhooti et al. ContinuousLy Adaptive Windowing Strategy (CLAWS): an automatic technique for achieving the best possible respiratory efficiency regardless of the breathing pattern, ISMRM Seventeenth Annual Meeting, Hawaii, 2009