Efficient 3D late gadolinium enhancement imaging using the CLAWS respiratory motion control algorithm

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Introduction: There has recently been considerable interest in high resolution 3D late gadolinium enhancement (LGE) imaging (1,2). These studies are performed during free breathing using diaphragmatic navigators to restrict the respiratory motion to a narrow window around the end expiratory pause position. Such techniques are inherently inefficient and, in the presence of respiratory drift and erratic breathing patterns, can result in very prolonged acquisition durations. While end-expiratory following techniques track the end expiratory pause position – thereby ensuring that the acquisition always completes – they may result in a variable amount of respiratory motion in the accepted data. The continuously adaptive windowing strategy (CLAWS)(3) was recently introduced to acquire free breathing data with a fixed acceptance window size in the shortest time possible for a given breathing pattern. With this technique, a first pass acquisition is performed (so that a complete dataset exists with a large range of respiratory motion) and based on subsequent diaphragm positions, data segments are then reacquired in a way that minimises redundant data. This technique was validated in whole heart coronary artery imaging and could potentially allow efficient acquisition of 3D late gadolinium enhancement data. However, changing the order of k-space acquisition in response to the respiratory position during gadolinium wash-out may potentially result in artefacts. This preliminary study was performed to investigate the use of CLAWS in 3D late gadolinium enhancement imaging.

Methods: A navigator gated inversion-prepared segmented FLASH sequence was modified so that the respiratory control was determined by the CLAWS algorithm(3). Three-D short axis LGE datasets (12 slices at 1.1 x 1.1 x 8mm, reconstructed to 24 slices at 1.1x1.1x4mm, alternate R-wave gating) were acquired in 4 subjects following inversion time (TI) scouting on a Siemens Skyra 3T scanner. The TI scouting was repeated immediately after and was followed by a second 3D LGE dataset using an unmodified commercially supplied end-expiratory tracking accept/reject algorithm (EE-ARA). Imaging was started 15 minutes following injection of contrast agent. Whole heart transverse 3D data were also acquired in 2 subjects on a Siemens Avanto 1.5T scanner (32 slices at 1.5x1.5x4mm, reconstructed to 64 slices at 1.5x1.5x2mm, single R wave gating) with both CLAWS and EE-ARA respiratory motion control. The respiratory patterns for all acquisitions were stored for subsequent analysis of the fastest possible scan times. The acquisition durations of the CLAWS and EE_ARA acquisitions were compared with a paired t-test. In addition, paired t-testing was also used to compare the acquisition durations against the best possible scan times which were determined from the simulations of the stored respiratory traces

Results: Image quality was similar for CLAWS and EE-ARA acquisitions with no apparent artefacts being introduced by the irregular k-space coverage in the CLAWS acquisition. An example is shown in Figure 1. Over all subjects, the acquisition durations were 354 +/- 189s and 512 +/- 269s for the CLAWS and EE-ARA acquisitions respectively (p = .03). Simulations of the stored CLAWS respiratory traces showed that there were no significant differences between the CLAWS acquisition times and the fastest scan times possible (354+/-189s vs 348 +/- 184s, p = ns) (Figure 2(a)). For the EE-ARA acquisitions however, the simulations showed that the acquisition durations were significantly slower than the fastest scan times possible (512 +/- 269s vs 300+/-150s, p =0.02) (Figure 2(b)).

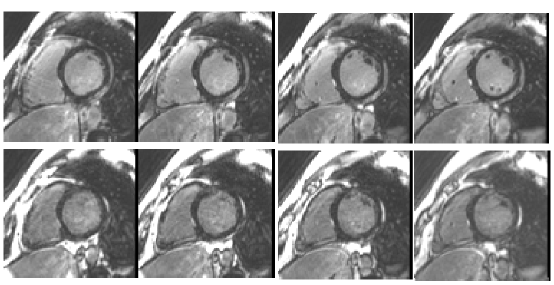
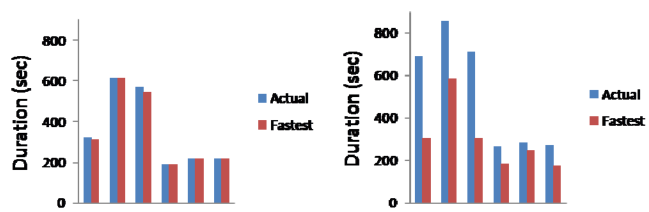


Figure 1: *Four contiguous slices from a 3D acquisition acquired with CLAWS (top) and EE-ARA (bottom). The acquisition durations were 323s and 692s respectively. Analysis of the respiratory traces showed that the CLAWS and EE-ARA acquisitions were performed in 97% and 44% respectively of the fastest possible scan times.*



(a) CLAWS *(b) EE-ARA*

Figure 2: *Acquisition durations in all 6 subjects (blue) together with the shortest possible acquisition durations, as determined from simulations of the stored respiratory traces (red) for both CLAWS (a) and EE-ARA (b) acquisitions.*

Conclusion: In this small patient cohort, the CLAWS algorithm allowed efficient acquisition of free breathing data in 3D late gadolinium enhancement imaging with no apparent artefacts arising from the non-smooth k-space acquisition order during gadolinium wash-out.

References: (1) Peters et al, Radiology 2007 (2) McGann et al, JACC 2008, (3) Jhooti et al., Magn Reson Med 2010