A 4D Single Breath Hold Cardiac MR Examination

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Introduction: Currently, the planning and acquisition of cine anatomical images of the heart ventricles is a time-consuming task that requires substantial expertise. Firstly, plan scans must be performed to identify the horizontal and vertical long axes. From these, short axis, two chamber and four chamber scans are acquired during multiple breath holds. Such a process typically takes around fifteen minutes, including planning and acquisition.

We have modified the recently described *kt*-BLAST technique [1] to enable us to acquire high-resolution cine volumes with approximately isotropic voxels covering the entire heart during a single breath hold. Isotropic voxels are a very desirable feature in these images because it permits reformatting of the volume in any orientation. Consequently, volumes can be acquired in the transverse orientation which is easy to plan. They can then be reformatted in any desired plane offline. This approach has the tremendous benefits that it removes the need for online scan planning and separate short axis and long axis acquisitions. Furthermore, it avoids the problems of misaligned short axis slices due to inconsistent breath hold positions and the substantial through-plane voxel anisotropy observed in conventional short axis images We applied this technique to six subjects and compared scan time (including survey scan and all preparations) and image quality with a traditional acquisition.

Methods: Following an initial survey scan to localise the heart, *kt*-BLAST volumes were acquired in the transverse orientation in 5 normal volunteers and 1 patient undergoing investigation for coronary artery disease. The images were acquired on a Philips Intera 1.5T with *kt* undersampling factor 5, and zero filled in the z-direction to produce 50-64 slices with a reconstructed voxel size of between 1.39x1.39x1.5mm and 1.93x1.93x1.5mm. Ten phases were acquired during a single breath hold.

For each subject, immediately following the *kt*-BLAST acquisition a set of scans were performed to obtain standard cardiac views. The images acquired were: short axis 2D multi-slice, two chamber long axis and four chamber long axis (SENSE factor 2, 20-40 phases, reconstructed voxel size of between 1.52x1.52x8mm and 1.84x1.84x10mm, taken in up to six breath holds).

The images were then transferred to a computer remote to the scanner. To simulate the offline identification of the vertical and horizontal long axes, the angulation and offset information from the standard images was used to identify the short axis, two chamber and four chamber views in the *kt*-BLAST images. Sinc interpolation was then used to reformat the *kt*-BLAST volumes into the short axis, two and four chamber orientations whilst maintaining the voxel dimensions.

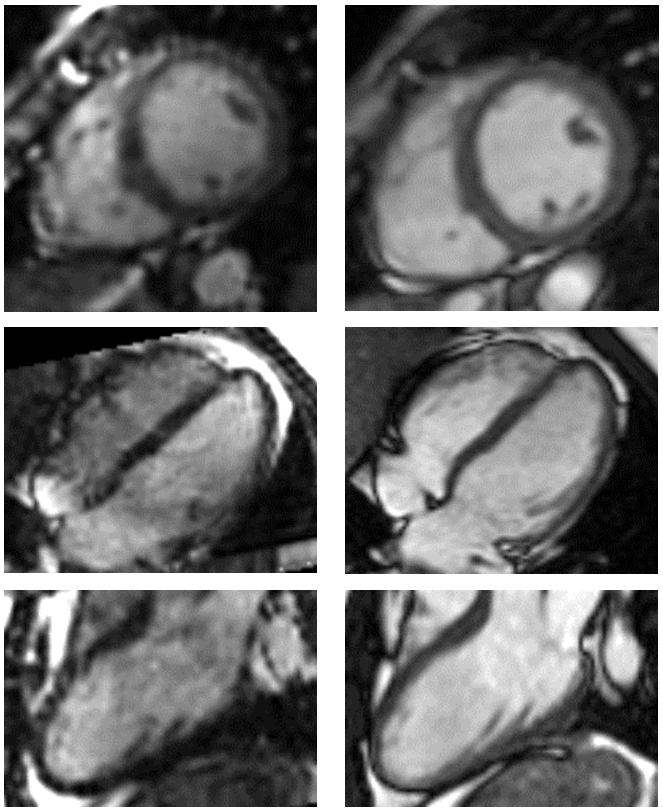

Figure 1: Reformatted (*left*) and corresponding conventional (*right*) views of the heart in short axis (*top*), four-chamber (*middle*) and two-chamber (*bottom*) orientations.

Results: The mean total scan time including survey scan for the *kt*-BLAST acquisitions was 5m31s. This contrasts to 15m50s for the conventional protocol. Figure 1 shows example of reformatted views shown alongside corresponding conventionally acquired images. Both the reformatted and conventional images exhibit good image quality. The signal to noise ratio is lower in the reformatted images due to the undersampling. In addition because the *kt*-BLAST technique does not correct for the coil's sensitivity profiles, image homogeneity is reduced in the reformatted image.

Conclusion: Using *kt*-BLAST to acquire 4D transverse images in a single breath hold followed by offline reformatting, we have demonstrated a reduction in scan time of a factor of three whilst maintaining high image quality. This has the potential to substantially reduce scan costs, increase scan availability by reducing the required skill of the operator, and open the way for cheap high-throughput cardiac MR examinations that are as easy to carry out as cardiac CT. Whilst we have demonstrated reformatting on *kt*-BLAST images, the results should be applicable to any other acceleration protocol, such as a 32 channel acquisition using a high SENSE factor.

References: [1] S. Kozerke, *et al.* Accelerating Cardiac Cine 3D Imaging Using *k-t* BLAST. *Magnetic Resonance in Medicine*. 52:19-26, 2004.