Assessment of ventricular function and dynamic anatomy using 4D cardiac data acquired in a single breath hold

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Introduction

Cardiac magnetic resonance (CMR) provides the capability of imaging in any plane. This allows assessment of dynamic anatomy (i.e. wall and valve motion) from 2D cines (i.e. 4 chamber, long axis and outflow tracts) and quantification of global ventricular function from 2D short axis multi-slice cines. Unfortunately, planning of imaging planes requires expert knowledge of cardiac anatomy, particularly in patients with congenital heart disease. The requirement of operators with sufficient knowledge of cardiac anatomy has been a hindrance to a more widespread use of CMR. In addition, acquisition of multiple cines requires multiple breath hold scans, which is time consuming and can lead to slice mis-alignment of the short axis stack, affecting the accuracy of ventricular quantification. KT-BLAST is an under-sampling and reconstruction algorithm that speeds up the acquisition of 4D cardiac data. This technique has previously been applied to multislice 2D and 3D volume cine data collected in the short-axis plane. The purpose of this study was to demonstrate the feasibility of using the KT-BLAST sequence to acquire 4D cardiac data in single breath hold that is orientated in the true axial plane (which is much easier to plan), and which has approximately isotropic reconstructed voxels.

Methods

In 5 volunteers and 1 patient images were acquired with a 1.5T cardiac MR scanner (Intera I/T MRI scanner, Philips, The Netherlands). 4D KT-BLAST cardiac data was acquired using an axial balanced fast field echo (b-FFE) sequence in a single 24-30sec breath-hold (TE/TR ~ 1.5ms/3ms, reconstructed voxel size ~ 1.5mm x 1.5mm x 1.5mm, KT-BLAST factor 5, phases 10). 4D data was reformatted into a short axis stack, 4 chamber and long axis slices for all phases. Standard 4 chamber (4CH), long axis (LA) and multi-slice short axis (M2D) cines were acquired using a b-FFE sequence (TR ~ 3.5ms, TE ~ 1.7ms, reconstructed voxel size ~ 1.75mm x 1.75mm x 8mm, SENSE 2, phases 20) in multiple 15-20 sec breath holds. Global ventricular function was assessed by measuring end-diastolic, end systolic volume (analyze, Mayo clinic, USA) and ejection fraction from the reformatted short axis (SA) stack (sixty 1.5mm slices) and the standard M2D stack (twelve 8mm slices). Wall motion was visually assessed using the 4CH, LA and SA views in the patient.

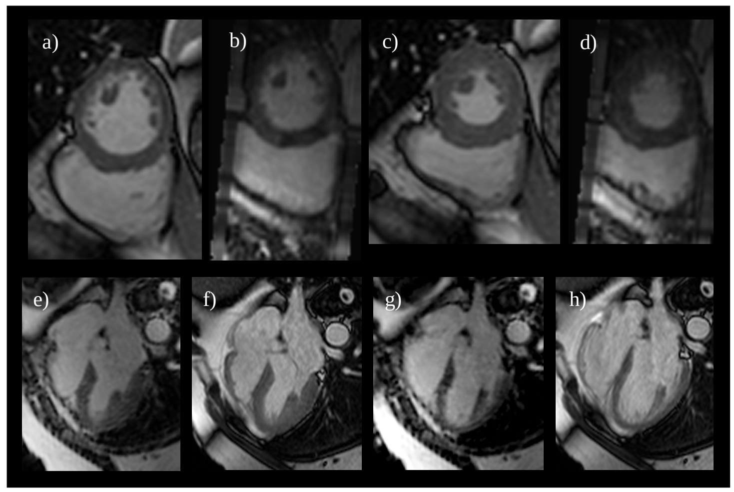

Fig.1. a) M2D SA slice diastole, b) reformatted 4D SA slice diastole, c) M2D SA slice systole, d) reformatted 4D SA slice systole, e) reformatted 4D 4CH slice systole, f) 4CH slice systole, g) reformatted 4D 4CH slice diastole, h) 4CH slice diastole,

Results

There was significant slice mis-alignment in M2D data, however due to acquisition in a single breath hold, there was no mis-alignment in the reformatted 4D data. The mean EDV was 120mls (±32mls) using M2D data and 109mls (±21mls) using 4D data, with no significant difference between the means ($p=0.5$). The mean ESV was 40mls (±15mls) using M2D data and 50mls (±15mls) using 4D data, with no significant difference between the means ($p=0.3$). The mean ejection fraction was 67% using M2D data and 55% using 4D data, the means were significantly different ($p=0.01$). Dynamic anatomy assessed with 2D cines, reformatted from the 4D data, were comparable to the traditionally acquired 2D cines in the 4CH, SA and LA (fig. 1).

Conclusion

We have demonstrated the feasibility of using KT-Blast to acquire 4D data, in the true axial plane in a single breath hold. We have also shown that such data can be reformatted over all phases, allowing assessment of dynamic anatomy and ventricular function. Currently a significant amount of time is required to plan and then acquire the multiple cines needed to assess dynamic anatomy and ventricular function. In addition, particularly in patients with congenital heart disease, expert knowledge of cardiac anatomy is required to plan image planes. Using this 4D technique, all information can be obtained within a single breath-hold without specialist planning, significantly reducing cardiac exam time. We have demonstrated that quantification of ventricular function can be accomplished using 4D data. However, there is a significant difference between ejection fraction calculated using 4D data and M2D data. This maybe due to insufficient temporal resolution in the 4D data, leading to higher ESV and thus lower ejection fractions. However, increased acceleration of 4D data acquisition through the use of higher KT factors will allows more cardiac phases to be acquired, improving the accuracy of global ventricular function quantification. Such high temporal resolution 4D cardiac data will allow quicker scan times, improving patient throughput, and offers the possibility of more accurate ventricular function quantification due to the removal of slice mis-alignment and partial volume affects.