Evaluation of Single Breath Hold 3D Cardiac Cine MRI using kat-ARC In Patients and Healthy Volunteers on 1.5T

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Target audience: Radiologists, cardiologists, and MR physicists with an interest in cardiac magnetic resonance

Background: The acquisition of multiple, contiguous 2D Cine balanced steady state free precession (bSSFP) slices through the heart is currently the reference standard for assessment of cardiac morphology and function. However, this approach is time consuming and requires repeated breath-holding and may lead to slice misregistration caused by variation in breath-holding positions[1,2]. The recently developed kat-ARC (k-adaptive-t Autocalibrating Reconstruction for Cartesian sampling)[3] is an auto-calibrating parallel imaging method with a k-t synthesis kernel to exploit both spatial and temporal correlation and local-cardiac-motion-adaptive temporal window selection for reducing motion blurring. Similar to prior-art kt Blast method[4], kat-ARC has demonstrated potential for high acceleration needed for volumetric cine imaging of the entire ventricle in a single breath-hold[5], and may provide a more efficient alternative to conventional techniques. The **aim** of this study was to prospectively assess the accuracy of three-dimensional (3D) kat-ARC balanced steady state free precession (bSSFP) for quantification of left ventricular (LV) end-diastolic volume (EDV), end-systolic volume (ESV), mass and ejection fraction (EF) in healthy volunteers and subjects referred for clinical CMR, using standard two-dimensional Cine bSSFP as a reference standard.

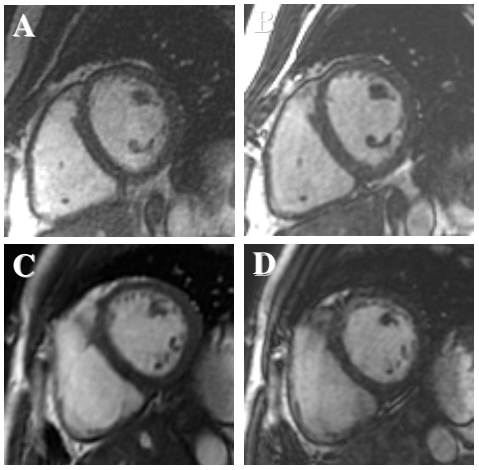

Figure 1: Short axis (A) 2D bSSFP, (B) Pre-contrast 3D kat-ARC in a healthy volunteer. Short axis (C) 2D bSSFP, (D) Pre-contrast 3D kat-ARC in a subject referred for CMR for dilated cardiomyopathy.

Materials and Methods:

Subjects: Five patients (5 males, age 36.0±11.0, heart rate 80±8 beats per minute (bpm)) with a clinical indication for CMR and 3 healthy volunteers (3 males, age 31.0±4.0, heart rate 56±12 bpm) were scanned according to an IRB approved and HIPAA compliant protocol. Conventional 2D Cine bSSFP and 3D kat-ARC sequences, oriented along the LV short-axis, were acquired on a clinical 1.5T MRI scanner (Optima MR 450w, GE Healthcare, Waukesha, WI). Short axis 2D Cine bSSFP was performed pre-contrast injection. 3D katARC was performed pre-contrast in all healthy volunteers and in 4 patients, and post administration of 0.15mmol/kg Gadobenate Dimeglumine IV in 1 patient referred for clinical CMR. Indications for clinical CMR included: non ST elevation myocardial infarction post coronary artery bypass graft, diastolic dysfunction, syncope, and dilated cardiomyopathy.

MRI protocol: 2D Cine SSFP parameters: FOV = 36 x 29-36cm (44x31 cm in one patient), TR 4-1-4.4ms (3.4 in one patient with large FOV), TE 1.0-1.1ms, FA 45 deg, Matrix = 256x192, Bandwidth 90.9kHz, Views per segment 12-16, Slice thickness 8 mm, slice spacing 0 mm. kat-ARC parameters: FOV = 360x270 mm^2, 2.0x2.0 mm^2 in-plane spatial resolution, 24 slices with 5mm thickness, TR/TE = 3.4/1.3 ms, Bandwidth 62.5 kHZ, net acceleration of ~8x, single breath hold with ECG gating. K-space was collected in a time-shifting fashion with variable density sampling with increasing acceleration from center to outer k-space[5]. During reconstruction, a static tissue removal scheme[6] was used to suppress residual artifacts and k-t synthesis with temporal window width of 4 cardiac phases determined at each specific phase was used to recover unsampled k-space data.

Analysis: Post processing of all images was done using QMass MR (Medis, Leiden, The Netherlands) to measure LVEDV, LVESV, mass and LVEF, by the same board certified radiologist. Differences in LV measurements between 2D SSFP and 3D kat-ARC in subjects and healthy volunteers were assessed using Bland-Altman analysis.

LV Parameter	2D SSFP	3D kat-ARC	Bland Altman Analysis
EDV (ml)	183±61.9	179.2±59.1	1.1 (-1.3, 3.5)
ESV (ml)	89.5±60.6	90.0±58.6	4.2 (-20.4, 28.8)
EF (%)	53.7±14.7	52.5±14.0	-0.4 (-11.2, 10.4)
Mass (g)	154.3±25.3	154.8±26.6	0.1 (-11.0, 11.2)

Table 1: 2D SSFP and 3D kat-ARC results reported as mean ± standard deviation. Bland Altman analysis reported as Bias and (limits of agreement). No significant differences were observed between 2D and 3D sequences.

Results: Actual scan time for 2D SSFP was 2.3±0.4 min (range 1.5-2.7 min). Total 2D SSFP acquisition time including breath hold pauses was 8.5±2.7 min (range 4.2-12.2 min). 3D kat-ARC datasets were acquired in 0.36±0.04 min (range 0.30-0.43 min or 18-26 seconds). Results of post processing and Bland-Altman analysis are summarized in Table 1.

Discussion: 3D kat-ARC bSSFP allows for volumetric CINE imaging of the heart in a single breath-hold in healthy volunteers and patients referred for clinical CMR. The bias observed between 3D kat-ARC and 2D bSSFP is clinically insignificant. As a result, this approach should enable substantial improvements in scanner time efficiency without sacrificing diagnostic accuracy.

References: [1] Makowski MR et al, *J Cardiovasc Magn Reson*. Jul 31;14:53(2012). [2] Liu J, et al, *Magn Reson Med*. May;63(5):1230-7(2010). [3] Lai P. et al. ISMRM 2009. [4] Kozerke S et al. Magn Reson Med Jul;52(1):19-26(2004). [5] Lai P et al. ISMRM 2011. [6] Lai P et al, ISMRM 2013.