Fast breath-held three-dimensional cine imaging using k-t BLAST for left ventricular volume assessment

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Introduction:

The sequence of choice for obtaining cine views of the heart for evaluation of left ventricular (LV) function is steady-state free precession (SSFP) due to its higher signal intensity, improved myocardium-to-blood contrast, and superior temporal resolution [1]. However, conventional techniques require multiple breath-holds that lead to increased examination time, patient discomfort, and potential slice misregistration. A shortened acquisition time is desirable, especially if it permits comparable quantification of LV function in a single breath-hold. Several groups have attempted to speed up the LV quantification process by incorporating parallel imaging techniques such as SENSE or SMASH [2,3]. Tsao et al. have recently demonstrated a fast volumetric cine imaging approach called spatial frequency-temporal frequency (k-t) Broad-use Linear Acquisition Speed-up Technique (k-t BLAST) that allows acquiring 3D volumetric cine images (with sufficiently high spatial and temporal resolution) with acceleration factors as high as eight by exploiting the inherent spatio-temporal correlations in cine cardiac data [4]. They demonstrated clinical feasibility in volunteers and in a small cohart of patients [5]. The purpose of this study is two fold: (1) to test if volumetric cine acquisition of the LV using k-t BLAST would yield quantitative parameters describing global LV function that is comparable to the conventional 2D SSFP sequence in volunteers and in patients, and (2) to evaluate the effect of contrast administration on volumetric cine images of the LV acquired using k-t BLAST.

Methods:

Patient Population : 36 subjects comprising 15 healthy volunteers (11men, mean age 34 ± 8.2 years) and 21 (16 men, 10 women; mean age,49 ± 12.2 years) consecutive patients were prospectively enrolled in this study. All subjects provided written informed consent.

Data Acquisition: All participants were imaged with a 2D SSFP sequence and a 3D cine k-t BLAST sequence. Imaging parameters for the 2D SSFP sequence were as follows: repetition time, 2.4-2.7 msec; echo time, 1.14-1.3 msec; flip angle, 65º; temporal resolution, 18-49 msec; in plane resolution, *2.2 x 2.2 mm;* and breath-hold duration, 10-12 heartbeats per section acquired. Imaging parameters for the the 3D cine k-t BLAST sequence were as follows: Field of view (FOV) , 280-400 mm * 280-400 mm, repetition time, 3.5-3.6 msec; echo time, 1.76-1.78 msec; flip angle, 45º; temporal resolution, 18-49 msec; in plane resolution, *2.4 x 2.4 x 12 mm;* and breath-hold duration 12-19 s (depending on the FOV and the heart rate), 12-18 heart beats for the entire LV volume. A k-t acceleration factor of 5 was used, and the training data was acquired in a separate breathhold lasting 6 s. The order of the two sequences was randomized, and two minutes within the administration of 0.2 mmol/kg of Gd-DTPA the 3D cine k-t BLAST sequence was repeated.

Data Analysis: All data sets were transferred to a post-processing workstation (ViewForum, Philips Medical Systems) for LV function analysis by two observers. End diastolic volume (EDV), end systolic volume (ESV), ejection fraction (EF), and LV mass were calculated using voxel summation. Mean values and standard deviation were calculated for each parameter, agreement between the two methods was assessed using Bland-Altman analysis, and statistical significance was assessed using ANOVA for repeated measurements (*P*-value < 0.05).2 observers accessed the LV volumes for all 108 image data sets. Region of interest (ROI) were drawn for the myocardium and LV in the basal, mid, and apical slices in all volunteers to measure the signal-to-noise ratio (SNR) and signal-difference to noise ratio (SDNR) between LV blood pool and myocardium.

Results:

Global LV functional parameters assessed using the three sequences are summarized in Table 1. Bland-Altman analyses revealed close agreement in the estimation of LV EF between the 2D SSFP and the 3D cine k-t BLAST techniquesThe LV EF calculated using 3D k-t BLAST cine imaging sequences was slightly lower (3.5%) than the 2D SSFP sequence. (Table 1) .The results from SNR analyses are presented in Figure 1 (below, right).

Conclusions:

In summary, it is feasible to obtain breath-held 3D volumetric cine images using the k-t BLAST approach with spatial and temporal resolutions comparable to conventional multi-slice 2D SSFP cardiac cine images in clinical patients. The quantitative parameters describing the global LV function calculated from the 3D k-t BLAST cardiac cine images are in agreement with those obtained from 2D SSFP cardiac cine images. The contrast between myocardium and LV blood pool in 3D k-t BLAST cine imaging techniques is slightly less than that of conventional 2D SSFP technique, and is particularly worse at the apical slices compared to basal slices. However, the myocardial to LV blood pool contrast in the apical slices can be improved by acquiring 3D k-t BLAST cine cardiac images after contrast administration.

	LV EDV (mL)	LV ESV (mL)	LV EF (%)	LV SV (ml)	LV Mass (g)
2D cine SSFP (1)	179.1 ± 46.3	77.7 ± 29.0	56.9 ± 9.8	101.2 ± 28.2	101.9 ± 29.0
3D cine k-t BLAST (2)	165.9 ± 43.6	77.7 ± 26.6	53.7 ± 8.7	88.6 ± 25.8	97.4 ± 30.1
3D cine k-t BLAST post contrast (3)	176.0 ± 43.1	82.7 ± 28.4	53.4 ± 9.2	93.4 ± 24.9	102.0 ± 27.0
Mean bias ± 2 SD 1 versus 3 1 versus 3	13.2 ± 25.6 3.1 ± 22.7	0.0 ± 13.9 -5.0 ± 15.0	3.2 ± 9.2 3.5 ± 8.5	12.6 ± 26.2 7.8 ± 29.9	4.5 ± 21.7 0.1 ± 33.9
P-value: 1Vs 2t 2 Vs 3 2- Vs 3	 <0.001 =NS <0.001	 =NS =0.001 <0.001	 <0.001 <0.001 =NS	 <0.001 =0.001 =NS	 =NS =NS =NS

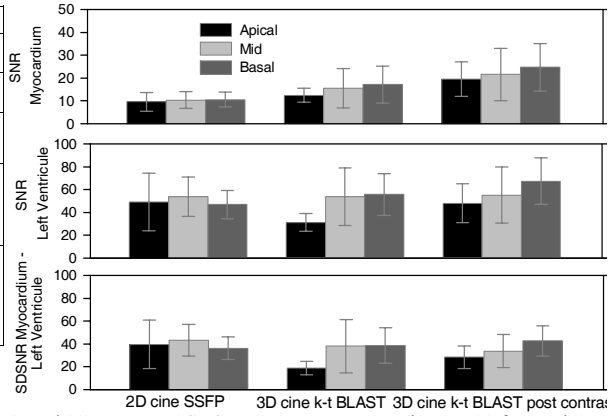

Figure 1 (right): The signal-to-noise ratios (SNR) of the myocardium (upper row), left ventricle (middle row) and SDSNR between myocardium and left ventricle (lower row) for 2D cine SSFP, 3D cine k-t BLAST pre and post contrast administration is shown above. Black, light gray and dark gray bars identify apical, mid, and basal slices. Note that the myocardial SNR progressively increased from 2D SSFP, 3D cine k-t BLAST pre- and post contrast sequences, and this increase was statistically significant across sequences. However, for a given sequence there was no statistically significant difference in myocardial SNR across slice locations. There was a statistically significant difference in SNR of the LV for the three different sequences, as well as across slice locations (middle row). Similarly for myocardial to LV contrast (SDNR) there was a statistically significant difference across three sequences as well as slice locations (bottom row).

References:

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