A novel ultra fast CMR approach for the assessment of left ventricular volumes and function in one breath-hold.

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BACKGROUND:
CMR is generally accepted as the gold standard for left ventricular (LV) volumes and function assessment. However, conventional cine imaging requires several breath-holds to cover the entire LV during 10-15 min. Recently, compressed sensing (CS) techniques emerged as a means to considerably accelerate data acquisition. CS principally relies on: 1) transform sparsity, 2) incoherence of undersampling artifacts, and 3) nonlinear reconstruction. (1-2)

PURPOSE: to compare a novel prototype CS single breath-hold multi-slice cine technique with the standard multi-breath-hold technique for the assessment of LV volumes and function.

MATERIALS AND METHODS: Twelve volunteers (75% male, age 33±8y) and 21 patients (86% male, age 63±14y) were included in the study. The novel prototype single breath-hold multi-slice CS cine sequence was implemented on a 1.5T MAGNETOM Aera (Siemens) MR System. Three long-axis and 4 short-axis slices were acquired in a single breath-hold of 14 heart beats (temporal/spatial resolution: 30ms/1.5 x 1.5mm2, acceleration factor: 11.0) (Fig.1A). The CS cine data were analyzed by the Argus 4DVF software (Siemens) which is based on a 3D LV-model that takes the motion of the mitral valve plane into account (Fig.1B). For gold standard comparison, a conventional stack of cine SSFP images was acquired (temporal/spatial resolution 40ms/1.2 x 1.6mm 2, slice thickness/gap: 8mm/2mm) and analyzed by the Argus VF software (Siemens). As a reference for the LV stroke volume (LVSV), the aortic flow (AoFlow) was measured by a phase-contrast acquisition (temporal/spatial resolution 40ms/1.8 x 1.8mm2) in 16 subjects (volunteers and patients without mitral insufficiency on echocardiography). The image quality of the CS and standard cine images were assessed based on recently published criteria (3).To assess intra- and inter-observer reproducibility of the CS technique, the CS cine images were analyzed by two experienced cardiologists (GV and PM).

RESULTS: The CS acquisition was more accurate than conventional approach for LVSV quantification: LVSV overestimation vs AoFlow was 6.4±6.9ml with CS vs 14.1±11.2ml with the standard approach (p=0.025) with less variability (r=0.91 vs r=0.79, respectively) (Fig3). The CS acquisitions showed an excellent image quality in 94% of the subjects and maintained quantitative accuracy in LV systolic function (CS-LVEF = 48.5±15.9% vs standard LVEF = 49.8±15.8%, p=0.11) with excellent correlation (r=0.96, slope=0.97, p<0.00001) (Fig.2). The intra-/inter-observer agreement for all CS parameters was good (slopes: 0.93-1.06, r: 0.90-0.99).

CONCLUSIONS: Accurate and reproducible measurements of LV volumes and function can be obtained in “one breath-hold” using this novel prototype multi-slice CS cine sequence with significant reduction of the scan time and potential clinical application.

Fig. 1 A: Planning of slice position (3 long axis and 4 short axis) on the localizers and acquisition in one breath-hold. **B:** Analysis by Siemens Argus 4DVF

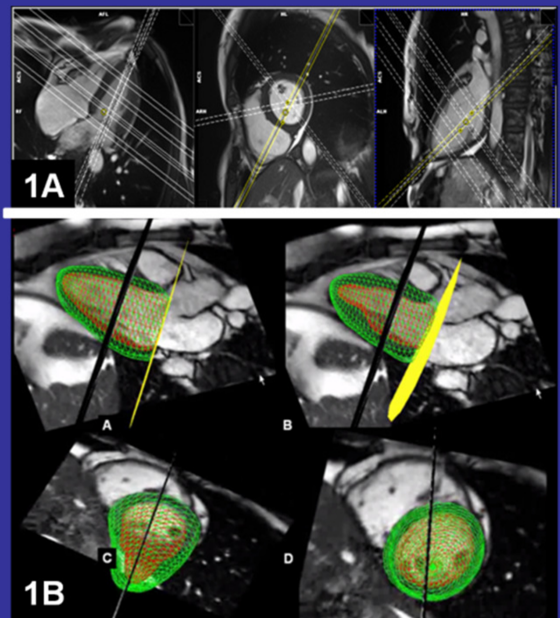


Fig. 2 Comparison of single-breathhold CS and standard multi-breathhold CMR for quantification of LVEF. Bland-Altman (A) and linear regression analysis (B)

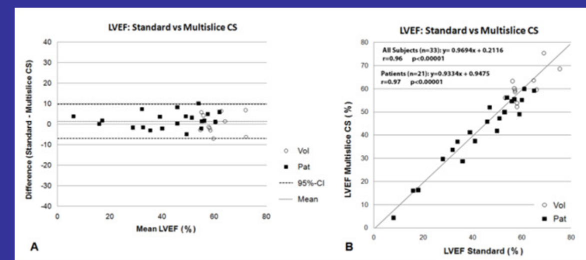
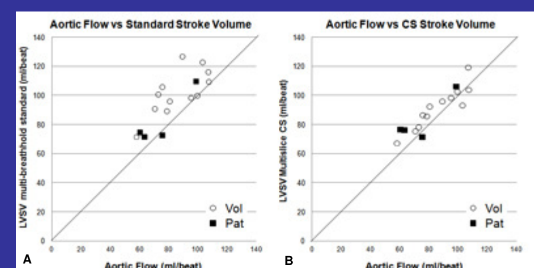


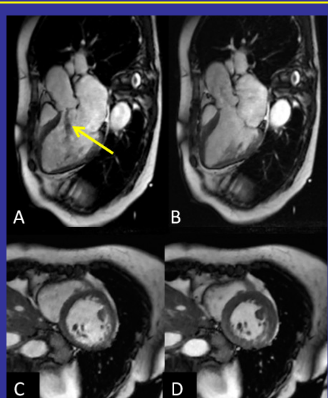
Fig 3 : Validation of the standard multi-breathhold (A) and the single-breathhold CS (B) CMR for quantification of LVSV vs aortic flow in the ascending aorta in 16 subjects (volunteers and patients without mitral insufficiency on echocardiography).



Clinical Case A:

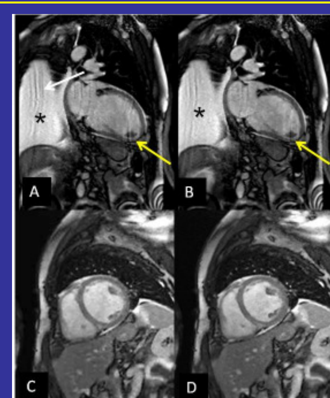
Example of a good quality CS acquisition in a 79 year-old patient with LV systolic dysfunction (LVEF=41%) and severe aortic regurgitation (regurgitation fraction 36%, arrow) performed before an aortic valve replacement.

A/B: 3-chamber view in diastole/systole. C/D: mid short-axis view in diastole/systole. Neither flow-related artifacts nor fold-over artifacts are visible in this case.



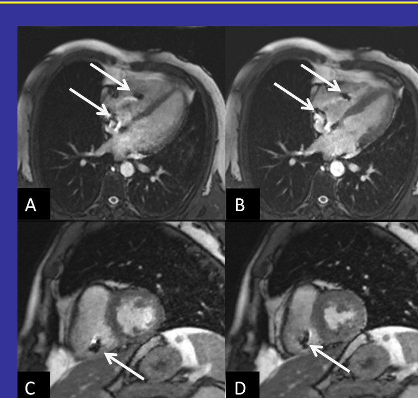
Clinical Case B:

CS acquisition in a 58 year-old patient with a dilated cardiomyopathy, a LVEF of 8%, an apical thrombus (yellow arrow), and pleural effusion (asterisk). A mild fold-over artifact is visible in the 2-chamber view (white arrow), but quality is sufficient to detect the apical thrombus.
A/B: 2-chamber view in diastole/systole. C/D: mid short-axis view in diastole/systole.



Clinical case C:

Good quality CS acquisition in a 56 year-old patient with a dual-chamber pacemaker (arrows; Medtronic Advisa DR MRI). The CMR examination was requested for the detection of myocarditis or infiltrative cardiomyopathy.
The pacemaker leads are visible in the right atrium and the right ventricle (arrows) without affecting the image quality yielding a quality score of 0 (=good).
A/B: 4-chamber view in diastole/systole.
C/D: mid short-axis view in diastole/systole.



References: 1) Lustig M et al. Sparse MRI: The application of compressed sensing for rapid MR imaging. Magn Reson Med 2007;58:1182-1195. 2). Tsao J, Kozerke S. MRI Temporal Acceleration Techniques. J Magn Reson Imag 36:543–560 (2012). 3) Klinke et al. Journal of Cardiovascular Magnetic Resonance 2013, 15:55