Accurate Left Ventricular Chamber Quantification is Feasible Using Cardiovascular Magnetic Resonance at 7T

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Introduction: Cardiovascular Magnetic Resonance (CMR) at ultrahigh field strengths (UHF) has begun to be studied, motivated by the enhanced signal- and contrast-to-noise ratio, which offers the potential to facilitate targeted tissue characterization and to open a broader access to (patho-) physiologic processes and mechanisms. However, it remains challenging due to electro-dynamic and other technical constraints. Therefore, it is unclear, whether LV chamber quantification at UHF is as accurate as CMR at 1.5T, which currently constitutes the gold standard.

Study aim: The present study explored the feasibility to assess left ventricular (LV) dimensions and function at 7T using improved spatial resolution enabled by the inherent traits of UHF and dedicated TX/RX RF coil technology together with 2D CINE fast gradient echo (FGRE) imaging. For comparison, LV chamber quantification has been conducted at 1.5T using standard steady-state free-precession (SSFP) and FGRE.

Methods: Six healthy male volunteers (mean age 36±10 years, range 27-52 years; mean body surface area 1.9±0.1m^2; range 1.75-2.04m^2) in sinus rhythm were studied. A stack of short axes parallel to the mitral plane covering the LV was obtained. At 1.5T (Avanto, Siemens Healthcare, Erlangen, Germany), SSFP (TE=1.2ms, TR=2.9ms, FA=80°, FOV=(340x340) mm, matrix 192x156, 30 phases) and FGRE (TE=3.9ms, TR=6.5ms, FA=15°, FOV=(340x340) mm, matrix 192x128, 30 phases) cine imaging with 7mm slice thickness (STH) and 3mm gap were used. At 7T (Siemens Healthcare), FGRE with 4mm STH / 2mm gap, and 7mm STH / 3mm gap, were applied (TE=2.7ms, TR=5.5ms, FA=35°, FOV=(340x340) mm, matrix 256x186, 30 phases). Acoustic cardiac triggering (ACT), which triggers image acquisition on the registration of the first heart tone (1), was accomplished since it is immune to interference with electromagnetic fields and magneto-hydrodynamic effects and hence does not suffer from mis-triggering, as frequently observed for conventional ECG. For reasons of consistency, ACT was also applied at 1.5T. Body and spine matrix coils were used at 1.5T. At 7T, a dedicated four-element transmit/receive loop coil (2) was connected to the 7T system via 4 T/R switches and a 1 to 4 RF power splitter with a CP-like phase setting for the four individual channels. Enddiastolic volume (EDV), endsystolic volume (ESV), ejection fraction (EF) and LV mass (LVM) were obtained by manually contouring the endocardial and epicardial borders in diastole and systole using the software CMR42 (CIRCLE Cardiovascular Imaging, Calgary, Canada), as exemplarily shown in figure 1 (short axis stack at 7T).

Fig. 1

Results: Image quality was diagnostic in all examinations. Figure 2 exemplarily shows a four- and two-chamber view and one midventricular slice obtained by the various approaches. 2D FGRE cine imaging at 7.0T provided excellent blood/myocardium contrast for all examined slice directions, even for views aligned parallel to the blood flow. Subtle anatomic structures, such as pericardium, valvular apparatus and right ventricular trabeculae were accurately identifiable. Mean quantitative LV results are depicted in table 1. LV-EF agreed well between all techniques. EDV assessed by FGRE at 1.5T was smaller (p=0.02) and LVM larger (p=0.07) compared to SSFP at 1.5T, which is already known and is attributed to different signal contrasts (3). Based on Bland-Altman analysis, mean differences and standard-deviation regarding EDV, ESV, EF and LVM between SSFP at 1.5T and the various FGRE approaches are depicted in table 2. Thereby, FGRE at 7T provided volumes and LVM with closer agreement to SSFP than FGRE at 1.5T. The best agreement regarding EDV and LVM was achieved with 4mm STH.

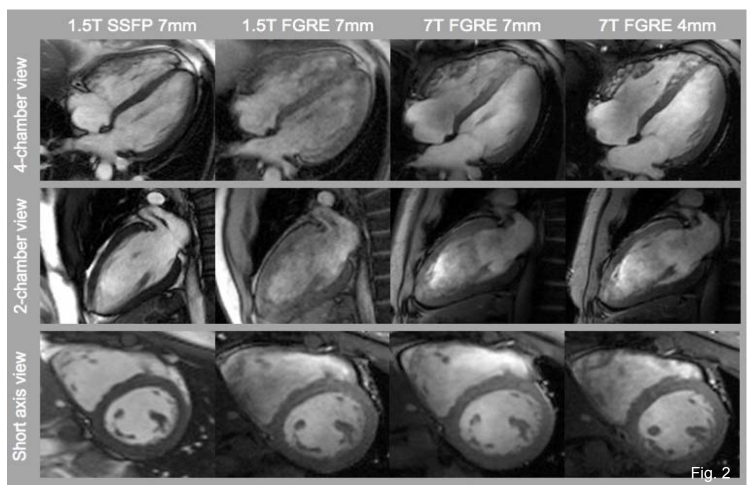

Fig. 2

Table 1 and 2

Field strength	Sequence	STH (mm)	EDV (ml)	ESV (ml)	EF (%)	LVM (g)
1.5T	SSFP	7	160.4±16.2	59.0±8.2	62.1±3.8	119.1±11.2
1.5T	FGRE	7	141.7±15.8	52.2±15.8	63.2±4.2	134.1±16.4
7T	FGRE	7	156.7±17.8	59.2±10.8	62.4±4.6	129.8±9.5
7T	FGRE	4	160.5±12.8	60.0±6.6	62.7±2.7	127.3±9.2

Field strength	Sequence	STH (mm)	EDV (ml) FGRE - SSFP	ESV (ml) FGRE - SSFP	EF (%) FGRE -SSFP	LVM (g) FGRE - SSFP
1.5T	FGRE	7mm	-18.8±8.2	-6.9±6.6	1.1±1.4	15.0±8.3
7T	FGRE	7mm	-3.7±8.3	0.1±6.5	0.3±1.9	10.6±6.3
7T	FGRE	4mm	0.1±8.0	0.9±5.5	0.5±2.2	8.1±3.1

Conclusion: Accurate LV chamber quantification is feasible using gradient echo based acquisitions at 7T, with close agreement to SSFP at 1.5T as the current gold standard. The combination of small STH and UHF together wit local TX/RX coils facilitated a sufficient SNR and CNR, which help to overcome the limitations of FGRE imaging at 1.5T and hence holds the promise for accurate functional cardiac imaging at 7T. Even more, the gain in SNR and in spatial resolution at 7.0 T opens the door towards right ventricular function assessment, which is elusive at lower field strength due to the competing constraints of spatial resolution, scan time and signal-to-noise ratio

References: (1) Frauenrath T et al. Invest Radiol 2009;44:539-47; (2) Renz W. Proceedings of the 26th ESMRMB. Antalya, TR, 2009; 476; (3) Moon JC et al. Radiology 2002;223:789-97;