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Feasibility of aortic valve planimetry at 7 T ultrahigh field MRI: Comparison to aortic valve MRI at 3 T and 1.5 T

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ABSTRACT

Introduction: This study examined the feasibility of aortic valve planimetry at 7 T ultrahigh field MRI in intraindividual comparison to 3 T and 1.5 T MRI.

Material and methods: Aortic valves of eleven healthy volunteers (mean age, 26.4 years) were examined on a 7 T, 3 T, and 1.5 T MR system using FLASH and TrueFISP sequences. Two experienced radiologists evaluated overall image quality, the presence of artefacts, tissue contrast ratios, identifiability, and image details of the aortic valve opening area (AVOA). Furthermore, AVOA was quantified twice by reader 1 and once by reader 2. Correlation analysis between artefact severity and employed magnetic field strength was performed by modified Fisher's exact-test. Paired *t*-test was used to analyse for AVOA differences, and Bland-Altman plots were used to analyse AVOA intra-rater and inter-rater variability.

Results: Aortic valve imaging at 7 T, 3 T, and 1.5 T with using FLASH was less hampered by artefacts than TrueFISP imaging at 3 T and 1.5 T. Tissue contrast and image details were rated best at 7 T. AVOA was measured slightly smaller at 7 T compared to 3 T (TrueFISP, p-value = 0.057; FLASH, p-value = 0.016) and 1.5 T (TrueFISP, p-value = 0.029; FLASH, p-value = 0.018). Intra-rater and inter-rater variability of AVOA tended to be slightly smaller at 7 T than at 3 T and 1.5 T.

Conclusion: Aortic valve planimetry at 7 T ultrahigh field MRI is technically feasible and in healthy volunteers offers an improved tissue contrast and a slightly better reproducibility than MR planimetry at 1.5 T and 3 T.

1. Introduction

With a prevalence of 33.9%, valvular aortic stenosis is the most frequent type of valvular heart disease in Europe [1]. Diagnostic aortic valve imaging is possible by echocardiography, catheterization, computed tomography, or cardiac magnetic resonance imaging (CMR) [2]. Choosing CMR, aortic valve imaging can be performed either by phase contrast imaging or by time-resolved cine imaging which allows planimetry of the maximum aortic valve opening area [2].

In the last decade, magnetic resonance systems with increased static magnetic field strengths have been developed and introduced in clinical routine. While 1.5 T could be considered the established standard magnetic field strength for clinical MRI systems, a significant market share of clinical MRI systems today operates at 3 T. Since about a decade, ultrahigh field (UHF) MRI systems operating at 7 T field strength have been introduced for research applications [3,4]. The increased field strength provides inherent advantages and disadvantages. On the one hand, the higher field strength inherently provides higher signal-to-noise ratios allowing for a higher spatial and/ or temporal resolution. Additionally, due to higher tissue susceptibility, higher magnetic field strength may improve tissue contrast [5–8]. On the other hand, use of clinical established cardiac imaging sequences may be limited, consequently True Fast Imaging balanced Steady-state free Precession (TrueFISP) may be hampered by artefacts at higher field strength MRI [9]. Furthermore, increased susceptibility and chemical shift artefacts as well as inhomogeneities of the B1 excitation field can interfere with ultrahigh field MR imaging [6]. The aforementioned factors render homogenization of the static magnetic field (B0

Abbreviations: SAR, specific absorption rate; UHF, ultrahigh field

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shimming) and homogenization of the excitation field (B1 shimming) crucial, especially in the cardiac region. Multi-channel B1 shimming of the transmit RF field at 7 T MRI is mandatory to provide homogenization of the signal excitation across the cardiac volume [10,11]. Simultaneously an increased power deposition (specific absorption rate, SAR) in the examined human tissue has to be monitored and, if necessary, limited.

Performing CMR at 7 T UHF is even more challenging. The

Table 1
Detailed sequence parameters of the acquired cine CMR sequences.

	1.5 T		3 T		7 T
	FLASH	TrueFISP	FLASH	TrueFISP	FLASH
TR [ms]	49.14	39.39	50.76	29.1	40.9
TE [ms]	3.45	1.36	2.89	1.27	4.76
Matrix [pixel]	208*136	208*170	208*141	208*144	240*196
Field of View [mm^2]	340*278	340*278	340*278	340*285	360*294
Flip angle [°]	15	54	12	38	70
Segments	7	13	9	10	5
Calculated phases	25	25	25	25	25
Spatial resolution [mm^3]	1.6 × 1.97 × 4	1.6 × 1.6 × 4	1.6 × 1.97 × 4	1.6 × 1.98 × 4	1.5 × 1.5 × 3
Voxel Volume [mm^3]	12.6	10.2	12.6	12.7	6.8
Temporal resolution [ms] (given a mean heart rate of 70 bpm)	2.8	2.8	2.8	2.8	2.8
Bandwidth [Hz/px]	253	925	445	1502	992
pMRI Grappa	R = 1	R = 2	R = 1	R = 3	R = 2
Number of active RF coil channels	20-32 Rx[a]	20-32 Rx[a]	20-32 Rx[a]	20-32 Rx[a]	8 Tx/Rx

FLASH, Fast Low-Angle Shot sequence; TrueFISP, True Fast Imaging balanced Steady-state free Precession; TR, repetition time; TE, echo time; pMRI, parallel MRI; RF, radiofrequency; Rx, receive; Tx, transmit;

[a] Using auto coil select mode. In TrueFISP relatively low flip angle had to been chosen due to SAR-restrictions.

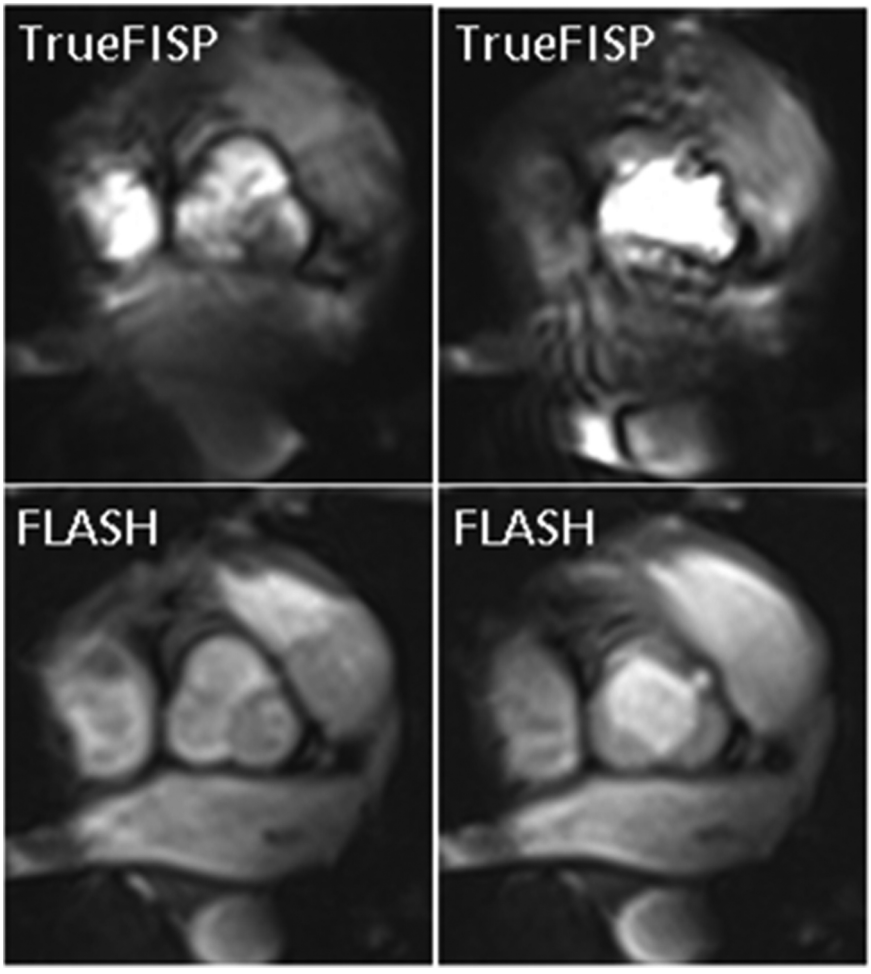

Fig. 1. Aortic valve imaging in a 29-years-old female at 7 T. On the left side the aortic valve is displayed in the closed state, while on the right side it is displayed opened. TrueFISP images were considerably hampered by artefacts, while FLASH images were less hampered by artefacts and provided sufficiently high contrast between blood pool and aortic valve rim.