

Clinical cardiac imaging at 7 Tesla: a validation study.

J. J. Suttie¹, L. DelaBarre², G. J. Metzger², P. F. van de Moortele², C. J. Snyder², P. Weale³, S. Neubauer¹, M. D. Robson¹, and J. T. Vaughan²

¹Department of Cardiovascular Medicine, University of Oxford, Oxford Centre for Clinical Magnetic Resonance Research, Headington, Oxfordshire, United Kingdom, ²University of Minnesota, Radiology Center for Magnetic Resonance Research, Minneapolis, Minnesota, United States, ³Cardiovascular MR Research and Development, Siemens Healthcare, Chicago, Illinois, United States

Background

High field strength cardiac magnetic resonance imaging (CMR) is attractive as a clinical research tool for its higher signal to noise ratio and its potential for increased resolution and improved contrast to noise in techniques such as perfusion imaging and magnetic resonance spectroscopy (MRS). Technical challenges include B₀ and B₁ field in-homogeneity, sub-optimal ECG performance and specific absorption rate (SAR) limits¹. This study was designed to validate the practicality and reproducibility of anatomical and functional cardiac imaging with Fast Low Angle Shot imaging (FLASH) and steady state free precession (SSFP) at 7 T validated against 3 T and the gold-standard 1.5T.

Methods

Subjects (n=3) were scanned within one month in a MAGNETOM 7T, MAGNETOM Tim Trio (3T) and MAGNETOM Avanto (1.5 T) system all running VB15A and with equivalent gradient systems (Siemens Healthcare, Erlangen, Germany). At 7 T, a 16 channel transceive stripline array, independently powered by 16 RF amplifiers (16x1kW), was tuned and matched to each subject¹. Electrocardiographic gating used the standard 3-lead Bluetooth based Vector Cardiogram system (Siemens Healthcare, Erlangen, Germany). At 1.5 T and 3 T standard clinical 12 channel receive arrays were used with the volume transmit coil. At 7 T, complex transmit B₁ field distributions were optimized with B₁ shimming for a tradeoff between transmit efficiency and homogeneity based on a rapid single breath-hold calibration scan². B₀ Shimming was performed with the shim volume localized to the heart. To further optimize image quality, especially at 3 and 7 T a “frequency scout” scan was performed to enable use of a B₀ offset to avoid off-resonance artifacts. On each scanner a short axis stack of images was acquired using both FLASH and SSFP. Scans were performed by the same experienced operator and independently analyzed using Argus (Siemens Healthcare, Erlangen, Germany) post-processing software to measure cardiac volumes, mass and ejection fraction.

Results

Reliable ECG triggering was obtained in all subjects, however more adjustment with respect to lead placement was required at 7 T than at lower field strengths. Images acquired using SSFP at 7 T had consistent B₀ related banding artifacts over the anterior and inferolateral walls despite local B₀ shimming and the selection of optimal offset frequencies to shift the artifacts outside of the region of interest. FLASH images were quantitatively superior at higher field strengths (SNR:1.5 T:99, 3 T:127, 7 T:355; CNR:1.5 T:52, 3 T:58, 7 T:205). Measurement of cardiac volumes, ejection and mass showed minimal variation between the 1.5 T, 3 T and 7 T field strengths for both FLASH and SSFP sequences (all ranges less than the clinical standard of 10%).

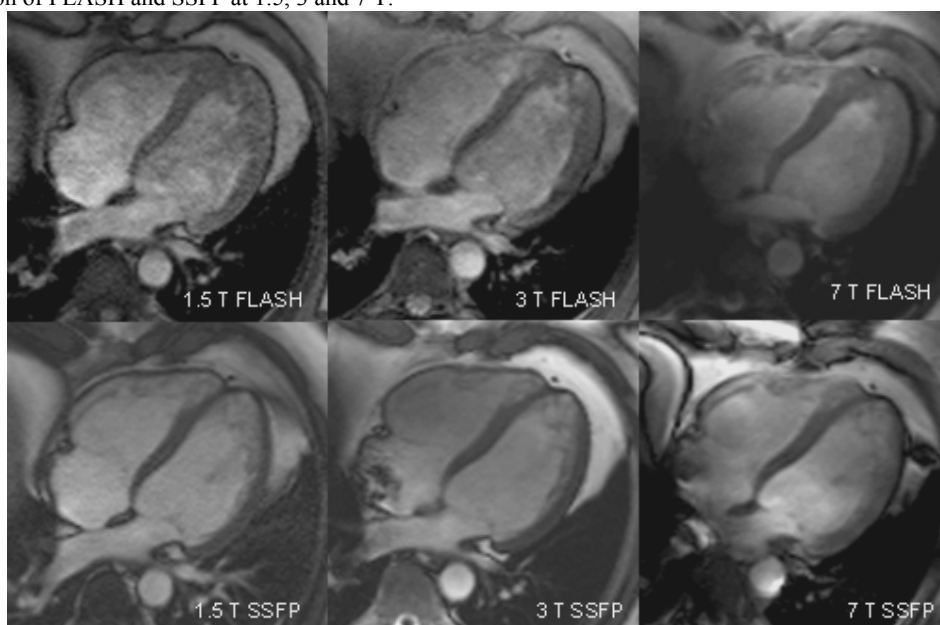
Discussion

FLASH imaging at 7 T is superior to FLASH imaging at lower field strengths, demonstrating both improved SNR and contrast (Figure 1). SSFP at 7 T suffers from residual B₀ artifacts, and while this finding does not prevent accurate assessment of volumes and masses, it might affect regional wall assessment. Further B₁ shim developments are expected to address residual local shading observed in some FLASH images at 7 T.

Conclusions

Using optimized sequences to minimize high field artifacts, assessment of cardiac volumes and function is practical and reproducible at 7 T. Measurement of cardiac volumes, ejection fraction and mass at 7 T with FLASH or SSFP are consistent with measurements made at 3 T and the clinical gold standard of 1.5 T.

Figure 1: Comparison of FLASH and SSFP at 1.5, 3 and 7 T.



¹ Snyder CJ, DelaBarre L, Metzger GJ, van de Moortele P-F, Akgun C, Ugurbil K, Vaughan JT. Initial Results of Cardiac Imaging at 7 Tesla, *Magn.Reson. Med.* 61:517-524 (2009).

² Van de Moortele P-F, Ugurbil K. Very fast multi-channel B₁ calibration at high field in the small flip angle regime. *Proceedings of the 17th Annual meeting of the ISMRM.* Hawaii, USA. 2009.