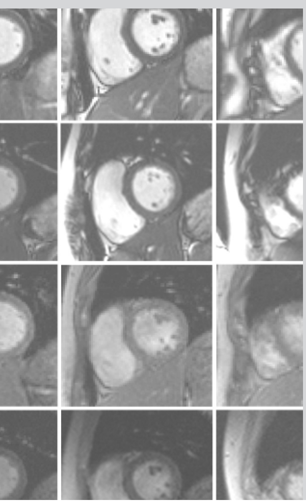  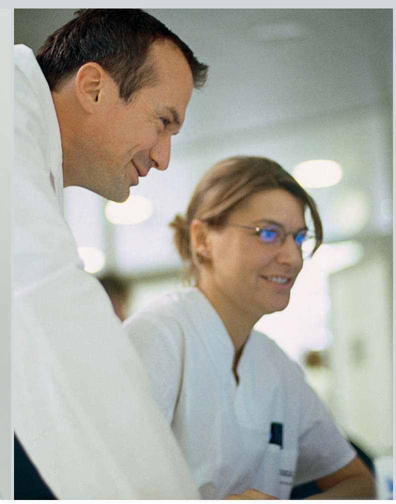 

MRI Hot Topics
Cardiovascular MR at 3T

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Cardiovascular MR at 3T

Vibhas Deshpande, PhD

Introduction

Cardiovascular MRI has the potential to benefit greatly from imaging at 3T. High-field offers higher signal-to-noise ratios, permitting faster or higher resolution cardiac imaging. Theoretically, the signal-to-noise ratio is doubled at 3T as compared to 1.5T, but there are potentially increased artifacts due to field inhomogeneities and higher susceptibility variations at the air-tissue interfaces between the heart and lung. Specific optimizations of hardware, pulse sequences, and imaging protocols are necessary to realize the exciting potential of 3T for cardiovascular MRI.

Cine Imaging

TrueFISP is the standard of cine imaging at 1.5T. It provides excellent blood-myocardial contrast with high signal-to-noise ratios. A similar application of trueFISP at 3T is also possible. Due to the higher SNR available at 3T, parallel imaging can be used to cut down the acquisition time by a factor of 2, or even 3, while maintaining adequate SNR. One limitation of trueFISP is its sensitivity to field inhomogeneities, which may cause artifacts in the cine images. Optimizing the imaging frequency helps to move these artifacts out of the region of interest. Another potential problem with trueFISP at higher magnetic fields is the specific absorption rate (SAR), which limits the flip angle. Since blood-myocardial contrast depends on high flip angle in trueFISP cine imaging, the CNR may be compromised if the flip angle is limited. Appropriate sequence design and RF pulse optimization have been performed such that a relatively high flip angle on the order of 50° can be achieved, providing a good blood-myocardial contrast, and minimizing image artifacts at the same time. Spoiled gradient-echo, or FLASH, cine imaging at 3T is greatly improved over that at 1.5T due to the higher signal. A comparison of the cine images acquired in the same patient at 1.5T and 3T using trueFISP and FLASH sequences is shown in Figure 1.

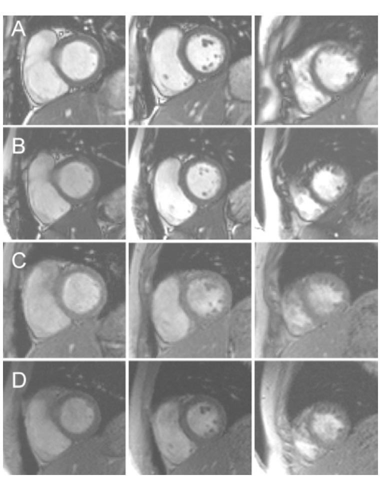

Figure 1. Cine images acquired at 1.5T and 3T using trueFISP and gradient-echo sequences. (A) TrueFISP cine at 1.5T, (B) TrueFISP cine at 3T, (C) Gradient-echo cine at 1.5T, and (D) Gradient-echo cine at 3T. Note that the trueFISP cine images are similar in image quality, but the SNR of the gradient-echo cine images is improved at 3T. (Courtesy: Dr. Henrik Michaely, University of California, Los Angeles)

This information about this product is preliminary. The product is under development and not commercially available in the U.S., and its future availability cannot be ensured.

First-Pass Imaging

High temporal resolution is a fundamental requirement of cardiac first-pass imaging. At the short TR's needed to achieve sufficient temporal resolution, SNR becomes a constraint for the turboFLASH sequence widely used for first-pass imaging. Imaging at 3T offers the immediate advantage of higher SNR at the same imaging speed. Parallel imaging techniques can be used to increase the temporal resolution and number of slices that can be acquired in a heartbeat. The lengthening of T1 at 3T is also beneficial in improving the background suppression. Images from different time points in a first-pass cardiac study are shown in Figure 2.

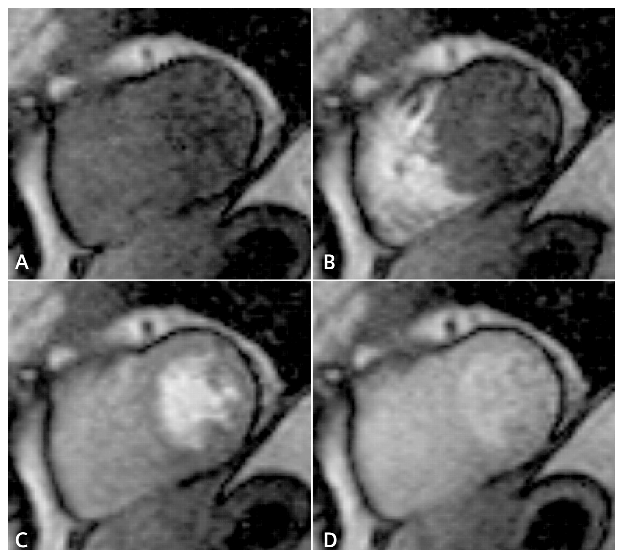

Figure 2. First pass cardiac imaging at 3T. A turboFLASH sequence with a parallel imaging factor of 3 was used to acquire the images. Notice that despite the high parallel imaging factor, the images show adequate SNR. (Courtesy: Dr. Qiang Zhang, Siemens CMR R&D, Chicago)

Delayed Imaging

Delayed imaging using IR-turboFLASH also stands to gain from imaging at 3T, as compared to 1.5T. This FLASH based technique is insensitive to field inhomogeneities or susceptibility differences, and thus can directly benefit from the higher signal available at 3T. Parallel imaging again can be used to acquire higher spatial resolution

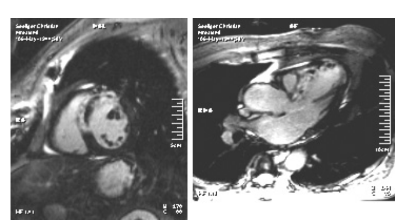

Figure 3. Delayed imaging with an inversion-recovery turboFLASH sequence. The infarct in the septum is clearly seen in the short axis and 4-chamber view. Note the high SNR and CNR in the images. (Courtesy: Dr. Regenfus, University of Erlangen)

images than at 1.5T, while maintaining signal and contrast characteristics. The images in Figure 3 demonstrate the high contrast and SNR of delayed imaging at 3T.

Tagging

Tissue T1 increases with increase in field strength. With longer myocardial T1, myocardial tag persistence is expected to be better at 3T than at 1.5T. Also, the higher SNR available at 3T permits the use of lower flip angle than is used at 1.5T, which also contributes to the longer persistence of tags in the muscle. In a preliminary comparative study of tagging between 1.5T and 3T, the tag conspicuity in the diastolic phases was found to be much better at 3T than at 1.5T. The persistence of the myocardial tags at 3T is shown in Figure 4. Note that the tags are clearly visible even in the late diastolic phase.

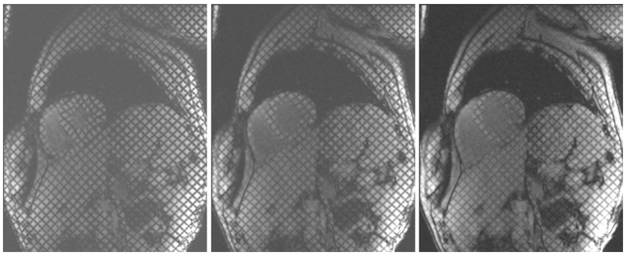

Figure 4. Myocardial tagging at 3T. Three phases are shown at times 145 ms, 425 ms, and 700 ms after the R-wave. Note also that the intensity of the tag pattern fades over time, due to longitudinal relaxation of the tagged spins. However, the tags are still clearly visible in the diastolic phase (700 ms).

Coronary MRA

Low SNR is a limiting factor for coronary MRA at 1.5T. In theory, an increase in field strength from 1.5T to 3.0T should result in a doubling of SNR, which can potentially allow for improved spatial resolution or reduced imaging time. Despite the limitations due to more significant B0 and B1 field inhomogeneity, coronary MRA shows promise at 3T. Figure 5 shows coronary artery images acquired at 3T, using the FLASH and trueFISP sequences.

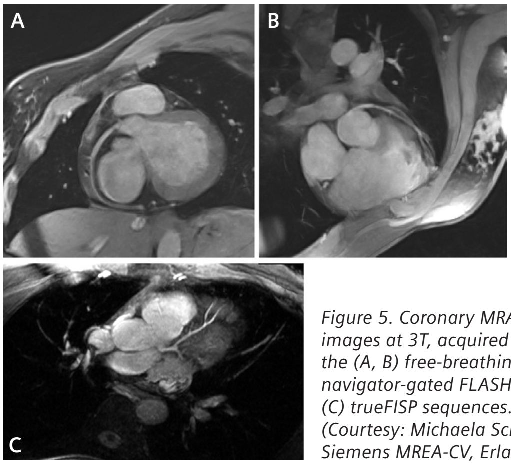

Figure 5. Coronary MRA images at 3T, acquired using the (A, B) free-breathing navigator-gated FLASH and (C) trueFISP sequences. (Courtesy: Michaela Schmidt, Siemens MREA-CV, Erlangen)

Magnetic Resonance Angiography (MRA)

The main advantage of MR imaging at 3.0 T is the signal-to-noise ratio (SNR) gain that scales approximately linearly with the field strength Bo from 1.5 to 3.0T imaging. Signal gain at 3.0T is an important factor to increase spatial resolution in time-of-flight and contrast-enhanced MRA and improve visualization of small vessel segments. Higher SNR also greatly contributes to faster acquisition times as higher receiver bandwidth can be used, and higher PAT acceleration factors. The susceptibility variations induced due to the gadolinium contrast agent itself are higher than at 1.5T, but it does not present a significant problem. This is demonstrated in Figure 6, which shows examples of carotid MRA, pulmonary MRA, and renal MRA, all showing excellent image quality.

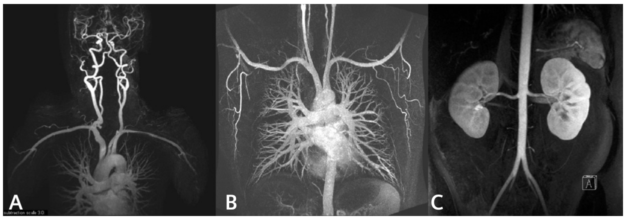

Figure 6. Contrast-enhanced MRA at 3T. (A) Carotid MRA. (B) Pulmonary MRA. (C) Renal MRA. Note the high SNR and high spatial resolution in the images (Courtesy: Dr. Kambiz Neal and Dr. Paul Finn, University of California, Los Angeles).

Plaque Imaging

Plaque imaging also stands to benefit from the improved SNR available at 3T. Plaque imaging techniques such as turbo spin echo (TSE) push the limits of spatial resolution, and therefore suffer from low SNR at 1.5T. Signal averaging is often required to achieve the spatial resolutions desired. The resulting longer imaging times may result in artifacts due to patient motion or swallowing. The higher SNR at 3T can be used to achieve higher spatial resolution and/or reduce imaging time. The potential of plaque imaging at 3T is demonstrated in Figure 7, which clearly identifies a plaque in the carotid artery wall.

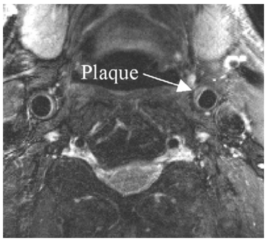

Figure 7. Carotid artery plaque imaging at 3T, using a TSE sequence. The plaque (arrow) in the left carotid artery wall has a fibrous cap and a lipid core. (Courtesy: John Koktzoglou and Dr. Debiao Li, Northwestern University)

Conclusion

The signal gain at 3T is a significant benefit for cardiovascular MRI, and can permit faster or higher resolution imaging. Applications using steady-state sequences such as trueFISP can be challenging due to their sensitivity to magnetic field inhomogeneities and SAR, both of which are higher at 3T. Nevertheless, with appropriate sequence design, many of these limitations can be overcome. Gradient-echo sequences and their applications such as first-pass and delayed imaging, and contrast-enhanced MRA, on the other hand, are relatively insensitive to field inhomogeneity and SAR, and offer immediate improvements due to the higher signal at 3T. For applications in which higher SNR is not directly needed, it can be traded for improved spatial resolution, temporal resolution, or reduced scan time.

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