7T Cardiovascular MRI: Is the Pain Worth the Gain?

VASCULAR

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When moving up to 7 Tesla, one is confronted with a number of challenges including higher specific absorption rate (SAR), enhanced susceptibility and chemical shift artifacts, and inhomogeneities in the B1 RF field. On the other hand, 7T provides enhanced sensitivity and some astounding new contrasts [1]. For the purposes of vascular imaging, 7T harbors several particular advantages. The purpose of this presentation is to illustrate the state-of-the-art in 7T vascular imaging and point out some key challenges and advantages for particular vascular techniques.

Non-contrast-enhanced angiography: Because of the lengthening of T1 with field strength, time-of-flight (TOF) techniques should deliver superior results at higher field strength due to improved background suppression. Owing to higher sensitivity, it should be possible to depict the vascular with higher spatial resolution. These theoretical considerations enable visualization of finer and more distal segments, such as the lenticulostriates [2,3]. In general, the contrast between blood and background tissue is enhanced at 7T for various types of gradient echo imaging, enabling for instance the acquisition of high-quality angiograms with sequences such as MPRAGE (Fig. 1), which opens up the possibility of simultaneously acquiring T1-weighted structural and angiographic images with perfect registration [4]. Nevertheless, issues such as SAR remain a limiting factor for techniques such as magnetization transfer and the application of saturation bands.

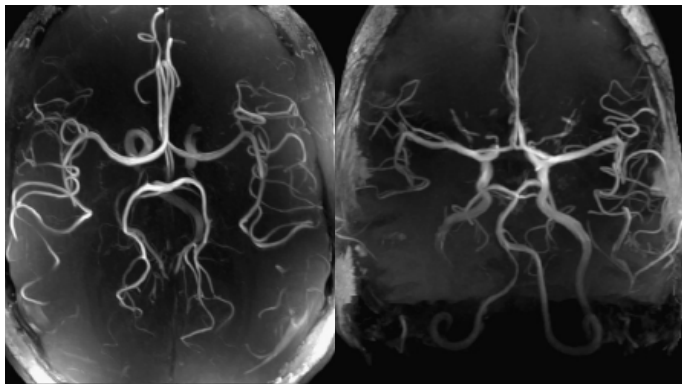

FIG 1. TOF (left) and MPRAGE (right) acquired at 7 T.

Contrast-enhanced angiography: The relaxivity parameters R1 and R2 of contrast agents are very field dependent. It is difficult to fully predict which properties will dominate at higher field strengths because many of the effects depend on the details of the injection protocol. First experience has shown that higher CNR for steady-state applications such as brain tumor characterization is obtained when using similar contrast dosages of gadolinium agents as at lower fields. For bolus angiography, the inherent high contrast between blood and background reduces contrast agent effectiveness [5]. Part of these difficulties derive from the use of local transmit coils, which implies that inflowing blood is not presaturated before entering the volume of interest.

Venography: Because of the susceptibility difference between deoxygenated venous blood and the surrounding tissue, venous imaging at 7T can produce extraordinary results. The use of a gradient-echo sequence with a relatively long TE to achieve T2* weighting produces excellent contrast of the venous anatomy. The susceptibility differences between tissue types also lead to differences in signal phase between these tissues. By optimizing the echo time to ensure that the signals are out of phase, contrast can be optimized in the phase image.

This information can be combined with the magnitude image to enhance tissue contrast, a technique termed susceptibility-weighted imaging (SWI). Figure 2 shows a 7T venogram after taking both magnitude and phase into account [6].

FIG 2. Venogram at 7T. The SWI data (TR/TE, 22/15 ms; acquisition time, 10 min; matrix, 512x384x72; resolution, 0.4x0.4x1.5 mm^3) were processed by multiplying the unwrapped and filtered phase image with the magnitude image. In addition, the 3-D median filtered SWI data set was subtracted and inverted. Courtesy of Alexander Rauscher (Institute for Diagnostic and Interventional Radiology, Jena, Germany) and Markus Barth (Erwin L. Hahn Institute, Essen, Germany, and F. C. Donders Centre, Nijmegen, The Netherlands).

Vessel wall imaging: Most angiographic techniques rely on depicting the lumen of the vessel with the aim of detecting stenotic lesions. However, it is increasingly recognized that plaque composition and geometry are much better predictors of plaque rupture and subsequent infarct compared with simple luminal narrowing [7]. Although such vessel wall studies are still outstanding at 7T, the higher SNR should be especially beneficial for increasing spatial resolution, and dedicated RF coils for examining, for instance, carotid plaques are now emerging [8,9].

In conclusion, high-field MRI of the vasculature at 7T is indeed a challenging endeavor associated with a certain measure of pain. However, even very early results have revealed tantalizing new capabilities for vascular MRI at 7T. At least for specific research questions, the gain is indeed worth the pain. Whether these benefits can be translated to the clinical setting remains to be explored in the coming years.

References

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