Migrating to 3T: Issues and Clinical Benefits!

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Background
3T magnetic resonance imaging (MRI) has undoubtedly become prime time and clinical routine for applications such as Neuro-imaging and MSK-imaging. As a result the available of 3T scanner systems is steadily increasing and thus respective systems are more widespread available these days. This continuous development therefore also pushes the use of higher field-strength in cardiovascular applications such as magnetic resonance angiography (MRA) and cardiac MRI in order to facilitate a flexible use of the installed 3T system base. However, specific changes that come along with the increase in $B_0$ have to be incorporated in most aspects of a cardiovascular MR imaging procedure; from patient screening to imaging technique details.

General Patient Population Issue @ 3 Tesla
Adjusting for the migration to 3T does even start before the examination. Potential ferromagnetic implants or metal inclusions have to be taken care of and approval for 3T safety and compatibility is required. In order to facilitate proper approval with access to widespread available databases, knowledge of specific implant types and model is mandatory (1). Although the majority of devices tested safe at 1.5T (although potentially conditional) this may prevent some patients of undergoing 3T scanning and in others specific scan protocol adjustments might be required for conditional devices.

Basic Changes @ 3 Tesla
Although more thorough details of changes at 3T will be covered elsewhere, few basic aspects would need to be pointed out:
- an approximately doubled signal-to-noise ratio (SNR) from 1.5T to 3T (2-6),
- a general substantial increase in RF energy deposition,
- changes in magnetic tissue properties and
- $B_0$ and $B_1$ inhomogeneities.

While most of these changes affect all aspects of cardiac imaging at 3T, some may only affect certain applications (e.g. assessment of myocardial iron overload). Although not directly affecting cardiovascular MR imaging, effects on physiologic monitoring units such as the magnetohydrodynamic effect also may impact cardiovascular MR imaging.

Clinical cardiac/cardiovascular MR imaging applications @ 3 Tesla

Contrast enhanced MRA
CE MRA protocols benefit from increased SNR at 3 Tesla and in addition from improved back ground suppression based on short TR and prolonged T1 values as compared to
1.5T. As general R1 properties of Gd-based contrast agents (GBCA) do show only a relatively minor decline as compared to the overall SNR gain, MRAs therefore do improve in regard to contrast-to-noise (CNR).

Late Gadolinium Enhancement (LGE) Imaging
LGE imaging is today's tool for evaluation of changes in myocardial texture such as myocardial infarction for assessment of viability or focal/spotty fibrotic changes as in assessment and differentiation of cardiomyopathies. The gain in SNR at higher B₀ also pushes the techniques CNR resulting in higher tissue contrast and thus faster imaging might be applied to either acquire higher spatial resolution periods or cover more volume within a given scan time or shorten required breath-holds (6, 7). However, to date a clear benefit towards clinical applications and especially a potential clinical impact such as relevant changes in therapeutic decisions have not been shown.

Myocardial Perfusion Imaging
At 1.5T first pass myocardial perfusion imaging is generally considered a relatively low SNR application which is mainly based on the demanding imaging requirements in regard to spatial and temporal resolution. The move towards higher B₀ allows for substantial SNR benefits and thus improved perfusion imaging quality (8). Evaluation of SI amplitudes at 3 Tesla as compared to 1.5 Tesla has demonstrated a significant increase potentially resulting in an improved SI time curve (9). Also the push for high-spatial resolution first-pass perfusion MR imaging has been made with promising results (10). In clinical application some investigators have demonstrated a clear benefit in terms of accuracy for myocardial perfusion imaging at 3 Tesla while other investigators failed to demonstrate a clinical impact (11). Although we anticipate a substantial benefit by means of visual assessment, the impact of improved perfusion SNR/CNR on clinical therapeutic decisions therefore remains questionable.

Cardiac Cine Imaging
Cine SSFP imaging is considered the workhorse of cardiac imaging. The technique is widely applied with a focus on cardiac functional and volumetric analysis but is also commonly used for planning and survey purposes as well as assessment of "dynamic" morphology in congenital heart disease (CHD) with its bright blood image contrast. Pronounced off-resonance banding artifacts though may hamper image quality of SSFP techniques at 3T. With proper adjustments and sequence tweaking image quality though can be maintained. Although based on properties at 3T image and tissue contrast might be slightly affected, the overall gain in SNR and CNR of cine SSFP in combination with proper imaging coil arrays allows to push spatial resolution and imaging speed thus often allowing faster volume coverage while maintaining volumetric accuracy (5). With modern 3T scanner technologies spoiled GRE is only rarely used as a scanning alternative in case of excessive off-resonance artifacts.

Other applications
For applications that deal with the evaluation of myocardial tissue properties or are based on physical effects that change at 3 Tesla, further evaluation remains necessary. This applies for T1 mapping, T2 mapping, assessment of myocardial iron overload
(based on T2* assessment) and potentially on imaging that are based on BOLD effects (12, 13).

**Conclusion**
The vast majority of applications benefit from 3 Tesla MR imaging; even SSFP cine imaging can be handled most times. However, while image quality can be improved in many cases there is limited prove on real impact on clinical decision making processes

**References**