Cardiovascular MRI: Vascular Flow & Angiography

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Highlights

- Accelerated acquisitions are the foundations for clinical high resolution Contrast-Enhanced MR-Angiography (CE-MRA).

- Dedicated acquisition designs exploiting the shorten relaxation times of contrast-infused blood are the basis of fast 3D CE-MRA acquisitions.

- Generic acceleration techniques such as partial Fourier and parallel imaging benefit greatly CE-MRA.

- Additionally, acceleration techniques using unique imaging update strategies have been specifically developed for time-resolved CE-MRA and Dynamic Contrast Enhanced MRI (DCE-MRI).

Technical Foundations: CE-MRA, Acceleration Methods

In the realm of need for speed MRI, Contrast-enhanced MR-Angiography (CE-MRA) is a particular application as it accepts a trade: namely signal-to-noise ratio (SNR) thanks to the signal boost obtained from exogenous contrast injection.

CE-MRA thrives for both high spatial and temporal resolution. First, spatial resolution is crucial to be able to accurately visualize the entire targeted vascular tree, and eventually its possible alterations. Millimeter and sub-millimeter resolution is now typically achieved in CE-MRA. Second, faster acquisitions are necessary to abide to practical constraints inherent to the rapid dispersion of contrast in the blood vessels but also to be more robust to motion, potential confounder when imaging at such a high spatial resolution. Third, both spatial and temporal resolution are sought after when performing time-resolved CE-MRA, or Dynamic Contrast Enhanced MRI (DCE-MRI), to be able to observe the course of a contrast time-bolus and extract quantitative perfusion parameters.

In this course, acceleration techniques employed in CE-MRA will be reviewed both in terms of their achievements but also in the potential artifacts they might introduce.

The primary acceleration of CE-MRA is achieved through streamlined examination. The simple structure of a CE-MRA examination proceeds with the use of a timing bolus combined with time-resolved CE-MRA to provide the optimal injection delay for timing high-resolution CE-MRA. Next in line, the sequence design and its optimization: dedicated RF pulses, gradient spoiler reduction, and short TR, allow for additional acceleration by benefiting from the shorten T1 relaxation time of spins in the contrast-infused blood.

Multiple common acquisition-reconstruction acceleration methods are also benefiting CE-MRA: partial Fourier and parallel imaging are generally combined for further acceleration. The specifics of these techniques will be covered: acquisition patterns, calibration processes and reconstruction algorithms. We will review both self-calibrated (e.g. GRAPPA) and explicit coil sensitivity estimation (e.g. SENSE) parallel imaging methods. Their improvements and their temporal correlation extension (e.g. kt-BLAST) will be analyzed in the context of CE-MRA (or DCE-MRI).

Finally, we will review acceleration techniques dedicated to time-resolved CE-MRA. Based on view-sharing techniques that increase imaging frame-rate while updating only a selected part of the k-space, multiple techniques have been proposed to provide high spatial and high temporal CE-MRA acquisition. The different MRI vendors' solutions for time-resolved 3D Cartesian acquisitions will be considered: keyhole (4D-TRAK), TRICKS, TWIST or DISCO. Within the same category of selective update of data for a dramatic increase of frame rate, constrained reconstruction such as HYPR and VIPR will be evaluated in the context of CE-MRA.

The presentation will conclude with an overview of the current state-of-the-art acceleration methods in CE-MRA, and highlight their potential, their limitations and their pitfalls.