MRA: A Dialogue Between a Radiologist & a Physicist

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Highlights

- Standard approaches for contrast-enhanced and non-contrast-enhanced MR Angiography will be reviewed in terms of methodology and clinical utility in an interactive setting co-presented by a radiologist and physicist.
- Motivation and implementation of newer MRA approaches, including dynamic contras-enhanced MRA with a contrast bolus and balanced SSFP MRA with and without cardiac gating
- Comprehensive hemodynamic assessment with 4D Flow MRI to assess vessel anatomy and hemodynamics

Target Audience

Those with interest in methodology and clinical applications of MR Angiography including physicians and scientists and current users of cardiovascular MR. No basic knowledge of cardiovascular MRI is needed, but basic knowledge of MRI in general is advised.

Objectives

- Understand the various origins of MRA contrast mechanisms with and without a contrast bolus.
- Understand the issues related to MRA imaging including design, acquisition and processing.
- Understand the benefits, pitfalls, and future potentials of these approaches.
- Guide users into tailoring MRA exams to specific clinical questions.

Purpose

Traditional clinical MR Angiography (MRA) provides volumetric datasets to characterize the vessel lumen. These MRA techniques can be generally separated into two categories:

- contrast-enhanced MRA, which requires the venous injection of a paramagnetic contrast agent in form of a Gadolinium chelate and
- non-contrast-enhanced MRA (NCE MRA), which relies on signal properties of the blood or the motion of the blood to create signal differences between the blood pool and the surrounding tissues.

Recent advances in MR hardware and accelerated imaging have facilitated significant advances in MR angiography approaches. This presentation will review the state of the art for diagnostic imaging in a dialogue format between a physicist and a clinician.

Methods

Time-of-Flight (TOF) and Phase-Contrast (PC) imaging have been developed as NCE Angiography techniques in the early days of MR imaging. However, widespread clinical adaptation of MRA did not occur until the introduction of CE-MRA [1] in the mid-1990's with significantly improved robustness.

CE-MRA acquisitions either target a single volume at peak enhancement or peak contrast with high spatial resolution or a time-resolved acquisition that compromises spatial and/or temporal resolution for the benefits of a dynamic acquisition similar to x-ray digital subtraction angiography (DSA).

Recent developments have renewed the interest in imaging approaches that do not rely on any external contrast agents [2, 3]. Advances in hardware, especially gradient amplifiers and multi-channel coil technology, have reduced imaging times, improved the signal-to-noise ratio, and reduced artefacts so that NCE MRA is becoming competitive again. For example, the short repetion times (TR) allow for imaging with the balanced SSFP sequence with or without cardiac gating (see Figure 1). These approaches provide viable alternatives in patients that are at risk for nephrogenic systemic fibrosis (NSF) and should not receive a Gd-based contrast agent. In addition, some of those approaches provide insights in functional information beyond the standard luminography.

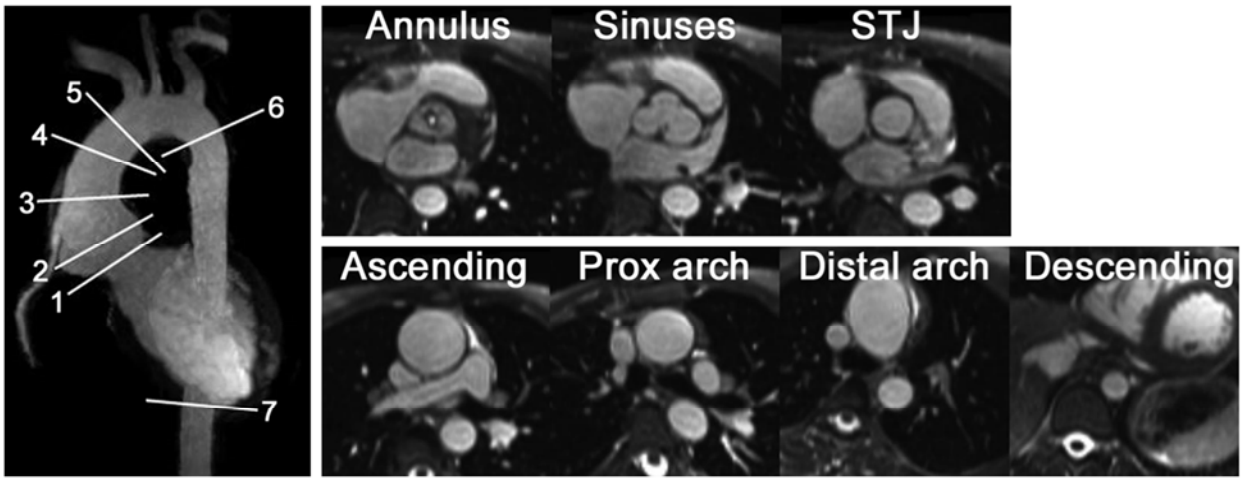

Figure 1: *bSSFP MRA of the thoracic aorta in a patient with a dilated aortic root. The volume rendered image on the left demonstrates the large coverage of the acquisition. Multi-planar reformats of the source images are shown at seven levels and provide high signal from blood due to the T2 over T1 contrast. Fat suppression was used in the ECG gated sequence.*

For example, arterial spin labeling (ASL) imaging can be used as a 'pseudo arterial injection' by labeling blood in targeted volumes and tracking its distribution over time. Novel '4D Flow MRI' imaging is an extension of traditional PC MRA to capture volumetric velocity vector fields throughout the cardiac cycle, thereby allowing for direct measures of hemdodynamic parameters such as pressure gradient, wall shear stress, pulse wave velocity, kinetic energy, and more [4] (see Figure 2).

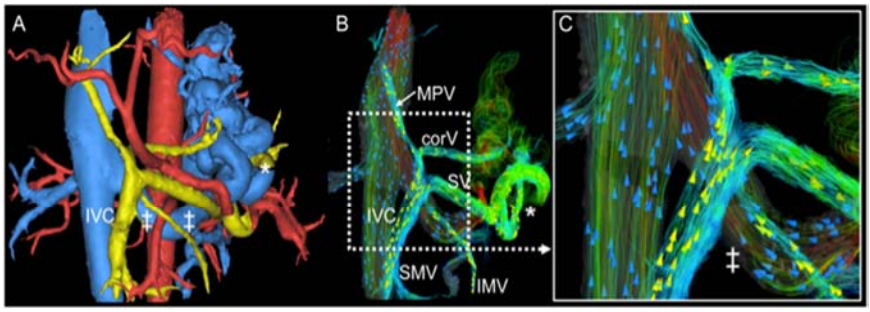

Figure 3: *4D flow MRI can visualize and quantify alterations in blood flow, which can be dramatic in patients with portal hypertension. In this 59yo patient with cirrhosis, large porto-systemic collaterals (*) and shunting into an enlarged left renal vein (‡) are easily seen, as well as reversed flow in the splenic vein (SV) and coronary vein (corV), and diminished by hepatopedal flow in the main portal vein (MPV).*

This lecture will provide an overview of CE MRA and NCE MRA approaches currently used in clinical practice. The underlying contrast mechanisms of CE MRA, time-of-flight, phase-contrast, balanced steady state free precession (bSSFP) [5], and ASL MRA [6] will be discussed in the context of tailoring MRA exams to specific clinical questions. Current and potential future roles of these approaches in clinical imaging will also be discussed.

References

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