Title of Session: Vascular MRI (intermediate)

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Highlights:

- Non-contrast enhanced MRA (NC-MRA) avoids the timing and spatial resolution constraints inherent to first-pass contrast-enhanced MRA (CE-MRA), as well as any potential risk from the contrast agent.
- Multiple technical approaches are being investigated. For the carotid arteries, several novel methods are being studied, including subtractive fast spin-echo (SE) and pseudo-continuous arterial spin labeling using an undersampled 3D readout. For the renal arteries, a respiratory-gated inversion-prepared 3D bSSFP technique has been well validated. For the peripheral arteries, 2D and 3D, subtractive and non-subtractive approaches are under investigation.
- Time-resolved NC-MRA is at an early state of development, but has the potential to provide useful information about the hemodynamic significance of arterial stenoses

TALK TITLE: Static and dynamic non-contrast enhanced MRA

TARGET AUDIENCE – Research scientists and physicians with an interest in the technical and clinical aspects of non-contrast enhanced MRA

OUTCOME/OBJECTIVES – Learners will glean an understanding of the basic principles and specific techniques being investigated for static and time-resolved NC-MRA, as well as clinical applications and limitations.

PURPOSE – This presentation will review the basic principles and techniques involved in NC-MRA of the extracranial carotid, renal, and lower extremity peripheral arteries. Both static and dynamic techniques will be presented.

BASIC TECHNIQUES

NC-MRA avoids the potential risk of nephrogenic systemic fibrosis. Moreover, it can salvage a clinical study in the event of a technical failure during a subsequent first-pass CE-MRA exam. Two-dimensional time-of-flight NC-MRA methods have been available for decades[1]. However, for the peripheral arteries at least, lengthy acquisition times (typically approaching an hour or more) and image artifacts have limited their routine use in favor of contrast-enhanced techniques. A range of NC-MRA techniques are being investigated, which are based on various contrast mechanisms and pulse sequences. Contrast mechanisms include non-subtractive (e.g. inflow-based, velocity-sensitive magnetization preparation) and subtractive (e.g. diastolic image – systolic image, phase contrast). Pulse sequences include 3D fast SE, 2D and 3D spoiled gradient-echo and balanced steady-state free precession (bSSFP), and non-Cartesian (e.g. undersampled radial).

CLINICAL APPLICATIONS

Extracranial Carotid arteries: 2D and 3D time-of-flight MRA techniques are generally accurate for characterizing stenoses involving the carotid bifurcation. However, artifacts from swallowing, respiratory, or recirculating blood flow often degrade image quality. Promising results have been obtained using ECG-gated subtractive fast SE. Subtractive imaging using pseudo-continuous arterial spin labeling in conjunction with a highly undersampled 3D radial readout can produce images rivaling the quality and field of view of CE-MRA.

Renal arteries: Of several NC-MRA techniques that have been evaluated, the best results are obtained using a respiratory-gated, magnetization-prepared 3D bSSFP pulse sequence. The magnetization preparation consists of an inversion pulse applied to the imaging volume, followed by a lengthy time delay to allow for the inflow of unsaturated spins.

Peripheral arteries: Subtractive approaches for NC-MRA of the peripheral arteries have been proposed which allow efficient depiction of arteries over large fields of view and suppress venous signal. These include ECG-gated subtractive 3D fast SE such as fresh blood imaging [FBI][2] and NATIVE SPACE [NATIVE = Non-contrast Angiography of the Arteries and Veins; SPACE = Sampling Perfection with Application Optimized Contrast by using different flip angle Evolution][3], as well as variants predicated on 3D bSSFP such as flow-sensitive dephasing[4]. Of these, subtractive fast SE MRA techniques have the most clinical validation for evaluation of the lower extremity peripheral arteries and are currently commercially available.

Gated inflow techniques using 2D gradient-echo pulse sequences have been used for more than a decade. These provide reasonable image quality and efficient venous suppression. However, scan times are long (typically >30 minutes) and image quality is poor for in-plane flow. Respiratory motion degrades image quality in the abdominal and pelvic regions. More recently, a non-subtractive NC-MRA technique called quiescent-interval single shot (QISS) has been described[5]. Several reports have shown that QISS can evaluate peripheral vascular disease with accuracy comparable to that of CE-MRA.[6,7] QISS has several advantageous features. For instance, it is highly robust with minimal sensitivity to patient motion and cardiac arrhythmias. It has the particular advantage of enabling a simple and efficient workflow, thereby eliminating the need for scout imaging or special technologist expertise. However, at the present time the technique is only available as a works-in-progress package.

Time-resolved NC-MRA: Time-resolved NC-MRA techniques are fundamentally different from time-resolved CE-MRA techniques, both in how they are acquired and in the meaning of "time-resolved". Time-resolved CE-MRA typically displays the passage of a bolus of contrast agent through a large region over durations of seconds to tens of seconds. The scans are typically accelerated using parallel imaging and/or view-sharing techniques. Several approaches for time-resolved NC-MRA techniques instead display variations in blood flow over the cardiac cycle with a time frame on the order of tens or hundreds of milliseconds. One approach for time-resolved NC-MRA involves repeatedly acquiring an ECG-gated NC-MRA with increments in the time delay after the R-wave. Another approach uses a golden radial acquisition that allows data to be retrospectively reconstructed into a cine series of time frames spanning the cardiac cycle.[8]

In summary, NC-MRA has made great strides in the last few years. In some cases, the techniques are commercially available, whereas for others additional clinical validation and commercialization are required. With continuing development, NC-MRA will be increasingly used as a viable alternative to CE-MRA.

REFERENCES

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