Robust NCE Techniques Remain a Viable Alternative for MR Angiography

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Non contrast enhanced magnetic resonance angiography (NCE-MRA) has become a global topic of interest following the recent link between nephrogenic systemic fibrosis (NSF) and gadolinium contrast agents.[1] Reports[2] dating to the year 2000 identify a scleromyxoedema-like cutaneous disease in renal-dialysis patients that may well have been associated with gadolinium; however, the link between NSF and MR contrast agents had yet to be made.

Gadolinium-based contrast agents are used in many MR examinations, but its use has it been of particular interest in NSF due to the larger doses of contrast required for cardiovascular imaging compared to MR examinations of other anatomy. Additionally, patients who receive an MRA of the renal arteries may have been at additional risk of NSF due to renal impairment.

The Clinical Impact

Many institutions implemented a policy of screening patients scheduled for a contrast enhanced MR imaging study to ensure adequate renal function prior to the administration of a gadolinium-based agent. If the patient exhibits impaired renal function that prevents the institution from performing an intravenous injection of a gadolinium agent, then non-contrast imaging is utilized. Imaging renally-impaired patients without a contrast agent presents a challenge when visualization of vascular structures is required.

NCE Techniques

GE Healthcare's Signa® HDx and HDe systems incorporate no less than 10 pulse sequences capable of imaging the vasculature without the use of a contrast agent. These include:

1. 2D Phase Contrast
2. 3D Phase Contrast
3. CINE Phase Contrast
4. 2D Time of Flight (gated and non gated)
5. 3D Time of Flight (includes MOTSA)
6. 2D fat sat FIESTA
7. 3D fat sat FIESTA
8. 3D FSE (black blood angio)
9. 2D Double Inversion Recovery
10. MR Echo* (FIESTA based real time sequence on HDx 1.5T)

The imaging challenge in assessing vascular anatomy without a contrast injection is deciding which sequence to use for interrogating the vascular anatomy of interest. As with all MR imaging sequences, there is a perpetual trade-off between resolution and scan time for obtaining the adequate signal-to-noise-ratio (SNR) in an image. With MRA, there is the additional consideration of blood flow when selecting the appropriate sequence.

3D Time of Flight (ToF) sequences (Figure 1) exhibit excellent spatial resolution; however, due to saturation effects and subsequent loss of signal, these are seldom used in slow

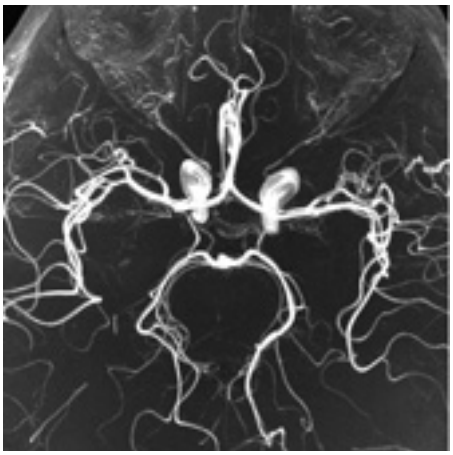


Figure 1. 3D ToF

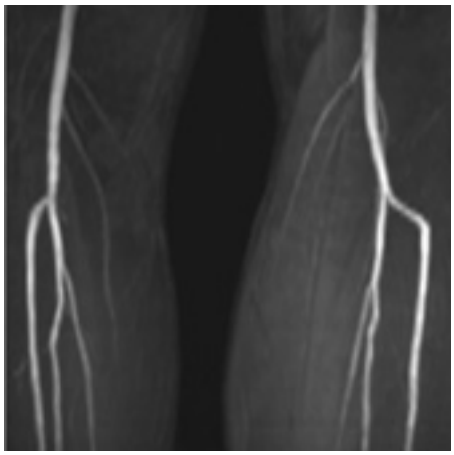


Figure 2. Gated 2D ToF

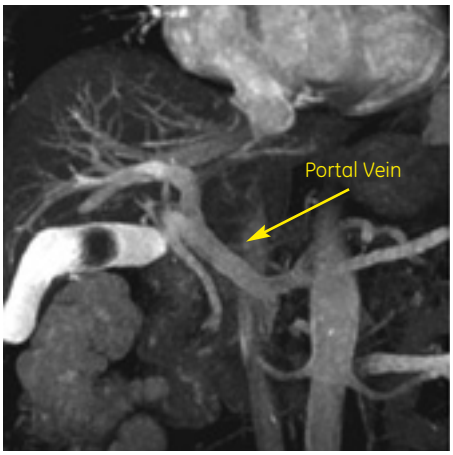


Figure 3. 2D FIESTA MiP

flow areas. 2D ToF techniques (Figure 2) may be utilized when imaging long vessels that have slower flow rates. In pulsatile vessels, the sequence should be gated to the patient's heart rate to mitigate artifacts.

Steady-state free precession sequences such as FIESTA (Figure 3) are excellent for fast scans done in a breath hold. When targeted to specific vascular anatomy, high in-plane resolution is easily achievable.

Phase contrast techniques provide excellent background subtraction resulting in 3D volumes (Figure 4) that are easily rotated into any viewing plane. 3D phase contrast techniques are significantly slower that the breath hold times seen with contrast enhanced techniques; however, when combined with a CINE acquisition, the phase contrast techniques are capable of quantifying flow in any vessel.

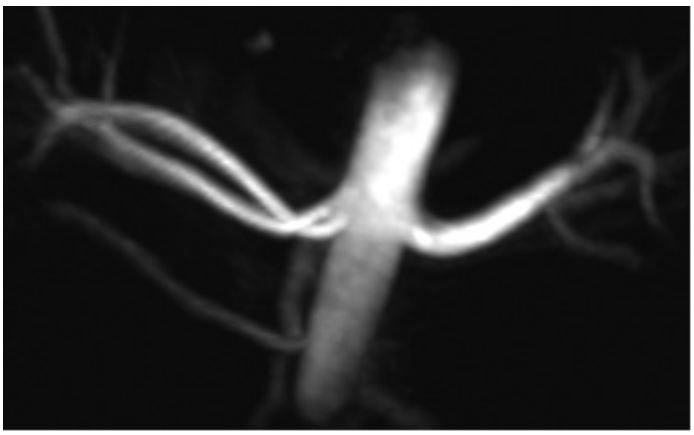


Figure 4. 3D Phase Contrast

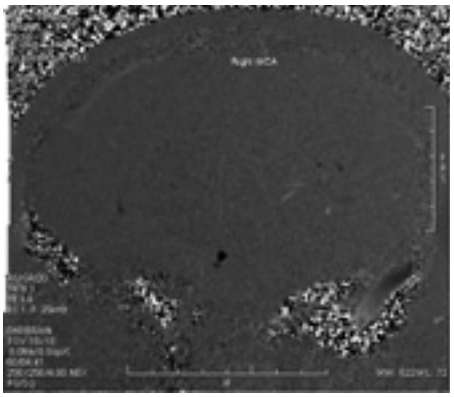
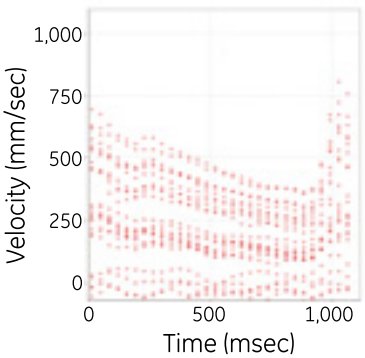


Figure 5. CINE Phase Contrast of middle cerebral artery and resulting flow measurements.



Peak Positive Velocity (cm/s)	83.1
Peak Negative Velocity (cm/s)	-6.07
Avg. flow (ml/beat)	3.122
Avg. Positive Flow (ml/beat)	3.158
Avg. Negative Flow (ml/beat)	-0.036

"For our non-contrast MRA studies, we generally rely on two complimentary techniques: 2D Time of Flight (to obtain images with venous suppression) and Steady-State Free Precession (i.e. FIESTA), that has very few flow artifacts. However, today most MRA studies are performed with sequences like eFGRE or using multi-phase, time-resolved techniques (e.g. TRICKS), which are very accurate and provide high diagnostic confidence. An additional advantage of these techniques is that one can also assess the dynamics of blood flow. This can be especially helpful in patients with shunts, fistulas or vascular malformations."

Steven Wolff, M.D., PhD, Director of Cardiovascular MRI, Advanced Cardiovascular Imaging, New York, NY

Phase contrast techniques are also sensitive to the flow direction of the blood – any flow from Left, Inferior or Posterior is shown as black and flow from Right, Superior and Anterior shown as white. Flow within the right middle cerebral artery (Figure 5) is from the left to the right and hence is black on the phase image. Also note that 3.122 mLs of blood passes through this vessel with each heart beat; multiplying this by the patient's heart rate (55 beats/min) generates the vessel flow rate at 171 mLs/min.

Future Pulse Sequences

Despite the comprehensive suite of non-contrast MRA sequences, GE Healthcare continues to evaluate improved techniques for imaging vascular structures without a gadolinium injection. FIESTA-based sequences that utilize various tissue preparation pulses are very promising in their ability to depict vascular structures in various anatomical locations.

Summary

MR provides robust visualization of vascular anatomy. In the subset of patients that are deemed unsuitable for a contrast injection, it is reassuring that many techniques exist on the Signa HDx and HDe scanners to image vascular anatomy and quantify flow. These techniques may prolong the exam time, but can be used to achieve the imaging goal. ■

References:

1. Thomsen HS. Nephrogenic systemic fibrosis: a serious late adverse reaction to gadodiamide. Eur Radiol. Epub October 24, 2006
2. Cowper SE, Robin HS, Steinberg SM, Su LD, Gupta S, LeBoit PE. Scleromyxoedema-like cutaneous disease in renal-dialysis patients. The Lancet 356(9234), 16 September 2000, 1000-1