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Invited commentary

Cardiovascular MR angiography

MRA is revolutionizing diagnosis of vascular pathology. Accurate diagnosis of cardiovascular pathology without requiring the risks of arterial catheterization, ionizing radiation and nephrotoxic contrast agents has been an ongoing challenge. Two articles in this issue of Cardiovascular MR by Stilman and Westenberg et al., demonstrate how advances in MR angiography now allow accurate diagnosis of peripheral vascular, renal, aortic and coronary artery bypass graft pathology.

This is possible because of the introduction of several advances described by these authors. MR imaging systems have substantially improved gradient performance that allows rapid imaging of extensive volumes of vascular anatomy during breathholding [1]. Some scanners are even fast enough to chase a contrast agent bolus down the legs to provide an anatomic map of the arterial anatomy of the entire lower half of the body with a single injection of contrast [2–6]. Another important advance is the understanding of how to optimize the imaging parameters. Many studies including that of Westenberg et al. show how the signal-to-noise ratio of the MR angiograms can be maximized by careful selection of the pulse sequence and imaging parameters. Perhaps the most important advance is the availability of gadolinium based paramagnetic contrast agents [7]. We now know these contrast agents to be free of clinically detectable nephrotoxicity even at high doses [8–9]. The gadolinium chelates currently in clinical use also have a very low incidence of allergic reactions [10]. A history of allergy to iodinated contrast is not a contraindication to gadolinium enhanced MR angiography and premedication with steroids or histamine blockers is not necessary. Using gadolinium chelates enormously increases the signal to noise ratio of the MR images. Higher quality studies are easily obtained by either using more gadolinium contrast or by injecting the gadolinium contrast faster for a higher arterial contrast agent concentration. New contrast agents with higher relaxivity are also in clinical testing [11]. Combined with the faster imaging hardware which can complete scans in a shorter amount of time, these fast contrast agent injections do not need to last very long and so the dose of contrast required for high signal to noise images is becoming less and less. Repeat injections of contrast are also possible although Westenberg et al. shows that repeat injections never enhance as well as the first because of background tissue accumulation of the contrast agent.

The advances in MR imaging system hardware and software have made imaging faster and image quality better but at the expense of making contrast agent bolus timing more critical. Both Stilman and Westenberg emphasize the importance of bolus timing for successful contrast enhanced MRA. In addition to the test bolus strategy or automatic detection (MR Smart Prep), described in their articles, it is also possible to improve bolus timing using MR fluoroscopy [12] super fast multiphase imaging [13] or 3D-TRICKS [14]. With MR fluoroscopy the arrival of contrast agent in the arteries is observed in real time so that the high resolution 3D spoiled gradient echo MRA sequence can be activated when the contrast arrives in the artery of interest for perfect synchronization of central k-space data acquision with the arterial phase of the bolus [15]. With multiphase imaging or 3D-tricks, the 3D imaging volume is acquired repeatedly at such short intervals that a bolus injection of gadolinium contrast agent will provide arterial phase enhancement for at least one entire 3D volume acquisition. For the test bolus timing strategy, we prefer to use an ultrasound content agent such as Optison (Mallinckrodt, St. Louis). This has several advantages: it does not introduce any gadolinium contrast into the patient prior to the MRA sequence. It can easily be repeated multiple times because it is very safe and only requires 0.1–0.3 ml to measure the circulation time and it disappears

in about three minutes. Furthermore, since the ultrasound bubbles are detected with an ultrasound scanner, this can be done outside the MR imaging system prior to the study to reduce the required magnet time.

As the quality of MRA improves, diagnostic accuracy and clinical utility also improves. But the details of image acquisition including parameter optimization from one patient to the next, breathholding, bolus timing and k-space mapping are becoming more and more complex. There are also subtle Fourier artifacts and computer reconstruction artifacts which must be understood to avoid diagnostic errors. This increases the training requirement for radiologists performing and interpreting these studies. It is essential to learn both the underlying physics and the clinical implementation for various anatomic regions. This is especially important as we take on the challenge of imaging smaller and smaller arteries that move with respiration and with cardiac contraction [16]. A whole new field of cardiovascular MR is emerging to revolutionize the diagnosis of vascular pathology. The barbaric days of arterial punctures, ionizing radiation and nephrotoxic poisons are giving way to the safe accurate patient-friendly approach of cardiovascular MR.

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