

Steady-State Imaging

What is steady-state MRA with blood pool contrast agents?

With steady-state imaging it is possible to depict the entire vascular system without appreciable loss of the contrast medium from the intravascular space. Steady-state MRA after administration of blood pool contrast agents can be performed after the initial passage of the contrast medium through the venous system. Depending on the individual circulation, image acquisition should begin approximately two minutes after contrast injection. Given that the intravascular concentration of the contrast agent remains stable in steady-state MRA, the acquisition time can be significantly prolonged in order to increase the signal-to-noise ratio and/or the spatial resolution.

Other options are to repeat measurements or to acquire motion-free images by synchronizing acquisitions to a particular part of the cardiac or respiratory cycle. ECG gating has been shown to improve quality in imaging of the carotid artery, thoracic or abdominal aorta. Respiratory gating is essential in measurements of all vascular regions exposed to respiratory movements including supra-aortal, thoracic or abdominal measurements (the latter including the renal arteries), when breath-holding techniques are not used.

How should steady-state images be read?

MR angiograms acquired during the steady-state phase depict not only the arteries but also the venous system. Both can be imaged simultaneously with extraordinary high resolution.

Although, at a first glance, steady-state images may appear much more difficult to read than first-pass images, image evaluation can be facilitated by:

- combined evaluation of first-pass and steady-state images
- cross-sectional 2D image data view of questionable vessel sections
- semiautomated evaluation with specialized software
- sophisticated post-processing algorithms as supportive additional tools for separating the arteries from the veins
- special acquisition methods including phase-contrast techniques for reducing venous signal

Blood pool contrast agents are administered by means of a bolus injection and can be used for both first-pass and steady-state MRA. One way of handling these image data is to use the first-pass images as a road map and the steady-state images for a detailed evaluation. This technique is very familiar to radiologists experienced in MRA (using extra-cellular Gd-based contrast media) where it is employed for validation or rejection.

tion of diagnoses of vascular pathologies made on the basis of high-resolution steady-state images. This can be done by evaluating the 2D images in the cross-sectional view of the suspicious vessel area. In this scenario, it is not necessary to subtract the venous enhancement from the arterial enhancement.

Artery-vein separation (AVS) tools are currently under development by the major MRI equipment manufacturers as well as by independent providers. They will be primarily based on semiautomatic methods. In these procedures, the central arterial and venous axes have to be identified by manual placement of seeds. After this has been done the software automatically separates arteries from the veins by a level-set framework and segmentation algorithms. Requirements of AVS software tools are a minimum of user interaction, a high speed for the post-processing process compatible with diagnostic clinical routine, and high quality – combined with reproducibility of the post-processing results.

Other methods to distinguish between arterial and venous vessel areas during imaging are in experimental stages. One of these methods takes advantage of directional-dependent, flow-induced phase sensitivity, allowing for the differentiation of arterial and venous signals. This technique was tested in the lower extremities, where opposite directional flow was successfully separated at mean flow velocities as low as 9 cm/sec. Limitations included smaller vessels with low velocity and vessels not axially oriented, as well as retrograde flow.

Can I do steady-state MRA imaging with ECCM?

Steady-state MRA is not possible with ECCM. ECCM are rapidly excreted by the kidneys, and hence do not provide an equilibrium or steady state in the vessel system. Furthermore, ECCM quickly extravasate into surrounding tissues, resulting in a reduction in intravascular contrast concentration. In other words, almost immediately after injection of ECCM, the perivascular space and background tissue are progressively enhancing while vascular differentiation and delineation become more and more limited.