Non-Enhanced Dynamic Digital Subtraction MRA in Cerebral Arterio-Venous Malformations

M. Essig[1], M. Bock[2]

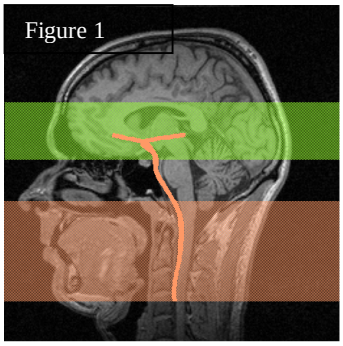
[1]Radiology, German Cancer Research Center, Heidelberg, Germany, [2]Medical Physics, German Cancer Research Center, Heidelberg, Germany

Introduction:

Cerebral arteriovenous malformations (AVMs) are congenital vascular malformations that result in direct arteriovenous shunts. Magnetic resonance imaging (MRI) and TOF-magnetic resonance angiography (MRA) have proven to be helpful supplements to conventional X-ray angiography for the assessment of patients with cerebral AVMs. Former studies have shown that due to vessel overlapping and the influence of formations with short T1 times (i.e. fat, bleeding and thrombus with methemoglobin) and is not able to give information on the hemodynamics of a the vascular malformation. The aim of our research was therefore to further improve the definition of the angioarchitectural components of the AVM by using a newly developed dynamic digital subtraction MRA based on the STAR technique (dMRA)

Methods:

Dynamic MR angiography was performed by tracking a blood bolus through a vessel structure using the STAR technique (Signal Targeting with Alternating Radiofrequency Sequences). Here, a bolus of blood is inverted by a 180^0 radio frequency (RF) pulse in a tagging slab upstream a slice of interest (Figure 1). The thickness and the orientation of the slice of interest is defined by the localisation and extension of the AVM. After a variable delay time TI the tagged bolus flows into and through the readout slice, where several raw-data lines of a series of images are acquired. The experiment is then repeated with the identical sequence timing but without the inversion of the blood signal. After a complex subtraction of the corresponding raw-data lines with and without tagging and a fast Fourier Transform, a series of difference images is created, that displays the inflow of the blood bolus into the readout slice with a maximal suppression of the surrounding tissue. Additionally, the sequence timing can be synchronized with the heart cycle (ECG-triggering) to minimize artifacts of pulsatile flow and to study the flow dynamics as a function of the heart cycle. In detail, a 180° inversion pulse tagged the flowing blood 100 ms after the R-wave in a transverse slice of 8-10 cm thickness 1 cm below the parallel imaging slice of 4 cm (Figure 1).



Additionally, to reduce the background signal from stationary tissue the readout slice was pre-saturated by a 90° saturation pulse. The time delay TI between the tagging and the data sampling was chosen at 100 ms to allow for the inflow of the tagged blood. Then eight rawdata-lines of eight images were acquired at 150 ms time intervals using a FLASH sequence timing with first-order flow compensation (TE = 8 ms, BW = 195 Hz/pixel). To achieve an acceptable acquisition time a 192x256 matrix was measured with zero-filling of high spatial frequencies. With a typical RR-interval of 800 ms, only every second heart beat could be used as a trigger-pulse, so that the total sampling time amounted to 2 aquisitions (with/without tagging) x 192 lines x 2 RR-intervals ≈ 10 minutes. With the used spatial resolution a sufficient signal-to-noise ratio of approximately 3 to 4 could be achieved.

Results

The dMRA technique proved to work out properly in the assessment of patients cerebral AVMs (Figure 2).The different AVM compartments, feeding arteries, AVM nidus, and draining veins were detected easily and best on the dMRA. The method also allowed to hemodynamically assess the malformations: small AVMs generally showed shorter shunt times, however, a short shunt-time was associated with a higher risk of bleeding.

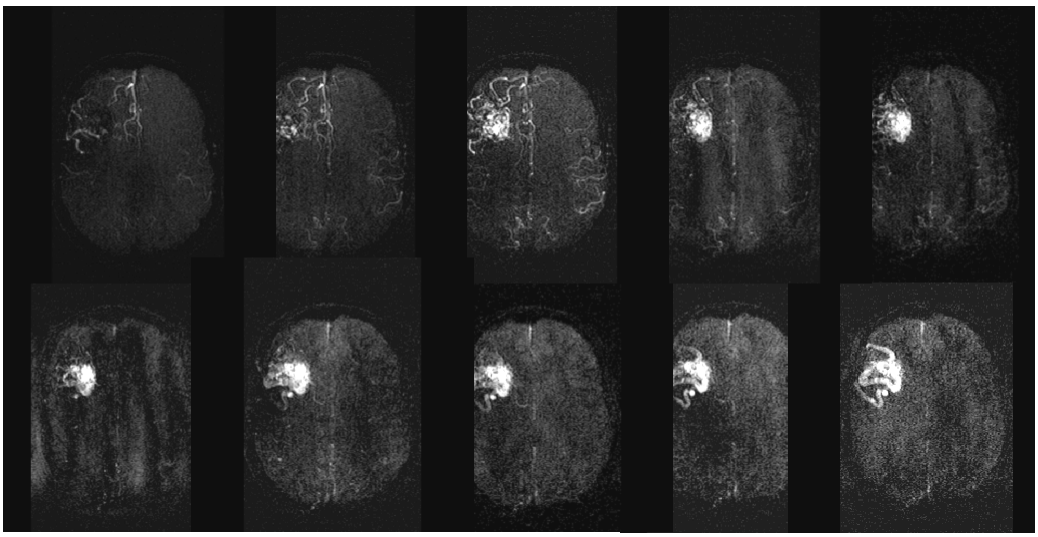


Figure 2:

10 dynamic angiograms achieved in a patient with rigth frontal AVM. The time delay varied from 100ms to 1000ms. The dynamic properties allow a detailed assessment of the feeding arteries at the short delay scans, the AVM nidus and the venous drainage patterns at the late scans.

Discussion:

DMRA is better suited that TOF-MRA to assess the AVM angioarchitecture. Additionally, the method allows to assess the hemodynamics of AVMs non-invasively. First clinical results have shown that the hemodynamic information, e.g. the AVM shunt-time, helps in the risk estimation for cerebral bleeding. Patients with a short AVM shunt time tend to bleed independent of the size of the malformation. Due to the lack of vessel overlap, the AVM nidus can be clearly defined and used as the treatment target volume for radiosurgery.