HYPR FLOW dynamic MR angiography in intracrianal arterio-venous malformations: comparison to TRICKS MR angiography and catheter angiography.

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Introduction:

For cerebral Arterio-Venous Malformations (AVMs), detailed evaluation of feeding arteries, nidus and venous drainage impacts the therapeutic decision. Digital Subtraction Angiography (DSA) is the current gold-standard imaging technique for AVMs, but is invasive. Recent interest for MR Angiography (MRA) as a non-invasive imaging alternative has increased, together with technical refinement of MR acquisition. For example, the Time-Resolved Imaging of Contrast Kinetics (TRICKS) MRA method is routinely used for the follow-up of AVMs [1]. Improvements of temporal and spatial resolution are still required to achieve accuracy similar to DSA. A novel hybrid phase contrast (PC) and CE MRA acquisition and HYPR reconstruction (HYPR Flow[2]) simultaneously provides 3D isotropic sub-millimeter spatial resolution and sub-second temporal resolution. The purpose of this work was to evaluate the performance of HYPR FLOW to characterize AVMs. We compared HYPR FLOW to TRICKS MRA, using DSA as reference for the assessment of the AVMs anatomical features and hemorrhage risk factors.

Methods:

Patients: Nineteen consecutive patients (7 women, 12 men; average age, 36.2 years; range, 18–58 years) with AVMs were included between September 2010 and August 2012 and underwent both MRA on a 3T MR scanner (Discovery MR750, GE Healthcare) and DSA examinations (Philips, The Netherland), within 15 days from each other (max. delay).

Image acquisition: the HYPR FLOW technique uses a post-contrast PC VIPR [3] acquisition to constrain the reconstruction of a dynamic Multi Echo VIPR, leading to an isotropic spatial resolution of 0.68mm and a temporal resolution of 0.5 sec. The 3D PC VIPR was acquired immediately after the TRICKS acquisition (to benefit from the 10 ml Gd-DTPA injection, as is usual for TRICKS acquisition) with the following parameters: FOV = 22 × 22 × 22 cm, 0.68 × 0.68 × 0.68 mm isotropic voxels, TR/TE = 8.3/2.9 msec, flip angle 20°, BW = 83.3 kHz, NEX = 0.75, acquisition time 5 min 35 sec. Encoding speed was 80cm/s. The Multi Echo VIPR was acquired 15 minute later, with a 5mL injection of Gd-DTPA (2mL/s), and the following parameters: FOV =22 × 22 × 22 cm, 1.7 mm isotropic voxels, TR/TE = 8.3/0.4 msec, flip angle 30°, BW = 125 kHz, NEX =1, frame update time = 0.5 sec, acquisition time = 1 minute. Linear registration was performed when patient motion occurred between the 3D PC VIPR and the ME VIPR acquisitions. The imaging parameters for the TRICKS acquisition were FOV = 25.6 × 22.5 cm, Voxels = 1.14 × 1.17 × 2.6 mm, TR/TE = 2.8/1.3 msec, flip angle 20°, BW =125 kHz, frame update time = 1.4 sec, acquisition, acquisition time 65 sec.

Image analysis: We compared the vascular enhancement kinetics in 10 AVM patients for the following parameters: Full Width at Half Maximum (FWHM) of the arterial peak and arterial diagnostic window [4] (AUC of arterial enhancement from Time [50% max arterial signal] to Time [50% max venous signal]). Vascular enhancement curves were obtained from circular ROIs drawned in the Internal Carotid Artery and the Longitudinal Superior Sinus on maximum intensity Projection images. Two neuroradiologists independently reviewed all the HYPR FLOW and TRICKS datasets. Characteristics of the AMVs were evaluated according to the Spetzler-Martin classification [5] (nidus size, eloquence of the cortex involved, deep venous drainage). Findings were compared to a consensual reading of DSA studies.

Results:

The curves of vascular enhancement kinetics displayed sharper vascular peaks for HYPR FLOW acquisitions than for TRICKS acquisitions (Figure 1). This resulted in a significant difference in favor of HYPR FLOW regarding the FWHM of the arterial peak (6.30 ± 1.25 vs. 13.30 ± 3.04 sec respectively; $p < 0.001$) and for the arterial diagnostic window (4.34 ± 0.91; 3.79 ± 0.84 respectively; $p = 0.025$).

HYPR FLOW datasets also better depicted the contrast progression through the AVMs (Figure 2), resulting in a trend for better agreement to DSA using HYPR FLOW for AVM characterization.

Agreement to DSA for the identification of deep venous drainage were excellent (κ= 0.89 – 1.00) using HYPR FLOW, and fair to substantial (κ= 0.39 - 0.77) using TRICKS. Agreement to DSA for the identification of venous ectasia was substantial to excellent (κ= 0.77 – 1.00) using HYPR FLOW and moderate to substantial (κ= 0.42 - 0.67) using TRICKS. Agreement to DSA for the identification of arterial feeders was excellent (κ= 0.86) using HYPR FLOW, and substantial (κ= 0.79) using TRICKS.

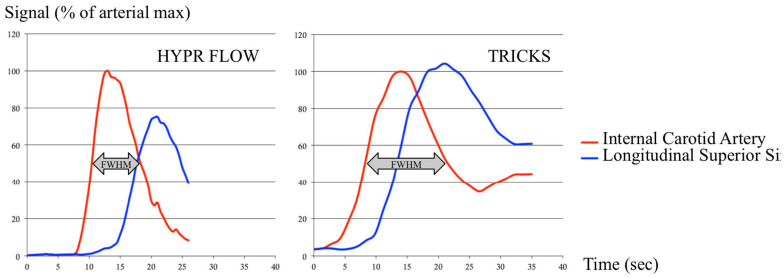

Figure 1: vascular enhancement kinetic curves from one AVM patient, from the HYPR FLOW study (left) and the TRICKS study (right).

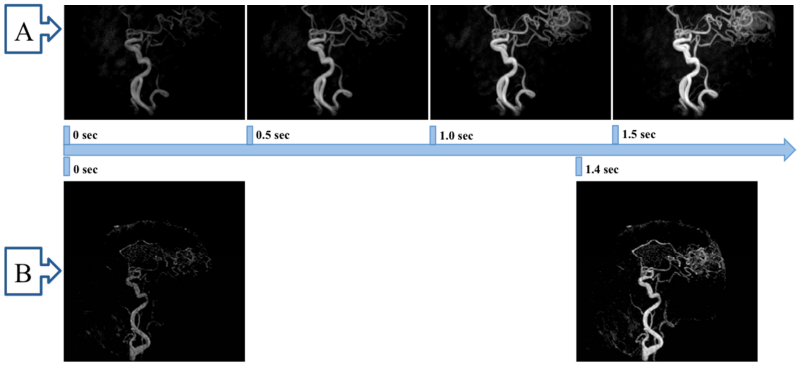

Figure 2: better depiction of the vascular bolus using HYPR FLOW (A) versus TRICKS images (B)

Discussion and Conclusion:

HYPR FLOW yielded better results than TRICKS for the parameters used to assess kinetics of vascular enhancement, thanks to higher temporal resolution combined with short intra-venous contrast injection. It suggests that HYPR FLOW best distinguished the arterial from the venous component. For clinical purposes concern, our results suggest that the HYPR FLOW method is superior to TRICKS for the characterization of AVMs, as it yielded better results for the identification of deep venous drainage, arterial feeders and venous ectasia, which are key parameters for the therapeutic decision in AVM management. However, two venous stenosis and one nidal venous aneurysm visible on DSA studies were not identified on MRA studies (but were retrospectively visible).

DSA remains the gold standard imaging technique for AVMs, but still these results are promising; once the workflow is automated in respect to online image reconstruction, HYPR FLOW could replace TRICKS or other dynamic MRA techniques for the non-invasive characterization and follow-up of AVMs.

[1] Petkova M, et al. JMRI 2009; 29:7–12. [2] Velikina JV, et al. JMRI 2010; 31:447–456. [3] Gu T, et al. AJNR 2005; 26:743-749. [4] Raoult H, et al. AJNR 2010; 31:1480–1487. [5] Spetzler RF, Ponce FA. J Neurosurg 2011; 114:842–849.