MR selective Flow-tracking cartography of brain vascular malformations

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Introduction:

Cerebral Arterio-Venous Malformations (AVMs) and Dural Arterio-Venous Fistulas (DAVFs) are characterized by an abnormal communication between arteries and venous vascular structures. Time-resolved Contrast-Enhanced Magnetic Resonance Angiography[1], susceptibility-weighted imaging[2,3] and MR Flow imaging[4] have already demonstrated their usefulness for the depiction of AVMs and DAVFs. But until now only Digital Subtraction Angiography (DSA) could provide a complete characterization of these malformations. In this study, we propose a virtual catheter-based like post-processing procedure applied on 3D velocity maps from 3D PC VIPR pulse sequence[5] to obtain a non-invasive MR complete cartography of brain vascular malformations. Here we compared this non-invasive MR cartography approach to the current gold standard, selective catheterization of the main arteries under DSA, in 10 patients with DAVFs or AVMs.

Methods:

Patients & Image acquisition: After Institutional Review Board approval, 5 patients with unruptured DAVFs and 5 with AVMs were prospectively included in this study. All patients underwent DSA while under local anesthesia, prior to endovascular treatment. For each patient, velocity-encoded MR data were acquired on a 3T MR scanner (Discovery MR750, GEHC) using 3D radial phase-contrast vastly undersampled isotropic projection reconstruction pulse sequence with retrospective cardiac gating (PC VIPR)[5] after injection of contrast agent (Gd-DTPA). Imaging parameters were: encoding velocity, 80 cm/s; imaging volume, 22x22x22 cm; TR/TE = 6,6/2,8 ms; BW = 83.3 kHz; isotropic spatial resolution: 0.68 mm; total scan time: 5min35, contrast bolus: 5 ml. 3D velocity maps were reconstructed from PC VIPR phase difference images[5] and imported into 3D visualization software (EnSight; CEI, Apex, NC).

Virtual MR Cartography procedure: It consisted of 3 automatic steps (Fig1-2): 1) segmentation of vessel boundaries; 2) manual positioning of plane emitter (vessel cross-sections) for a standardized selection of arteries (internal carotid, external carotid, vertebral arteries); 3) blood flow tracking within these volumes through the velocity map based on streamlines computing using Ensight.

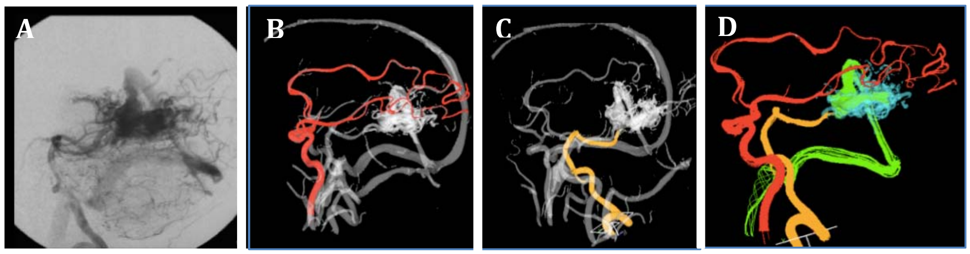

Figure 1: Representative AVM case. A: Selective DSA; Virtual flow tracking of left internal carotid (B) & left vertebral artery (C); D: Complete MR cartography with venous draining within the transversal sinus (red).

Results:

In all patients, virtual MR Cartography procedure provided a selective cartography of the vascular components involved in the malformation (Fig. 1.D). Figure 1 displays a comparison between DSA and this technique for an AVM. We identified the arterial feeders of the malformation, the nidus location, and the venous draining, consistent with DSA (A). Virtual MR Cartography of the 5 DAVFs allowed to obtain a Cognard MR classification[6], consistent with DSA findings, thanks to a selective MR cartography of the fistulas including arterial feeders, draining veins, arterio-venous shunt location, and presence of cortical venous reflux and ectasia (Figure 2).

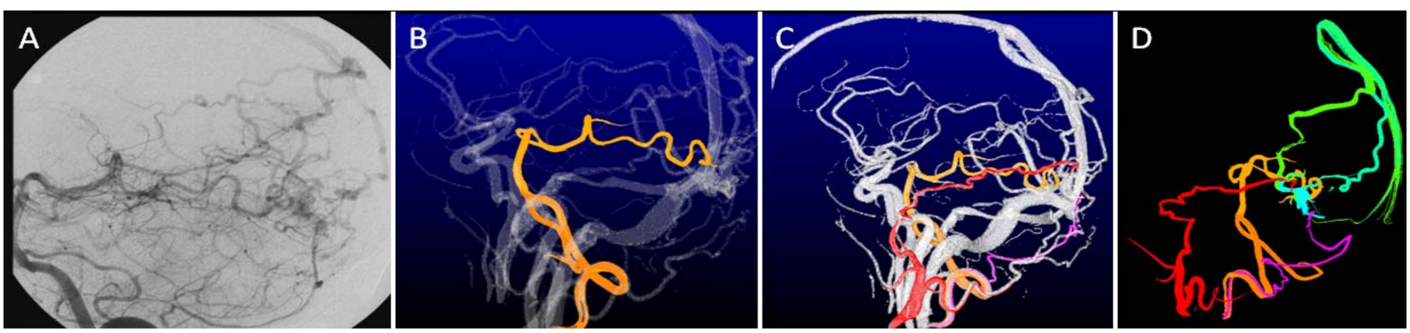

Figure 2: DSA (A) and virtual MR Cartography (B,C,D) of a type III DAVF.
A: Selective DSA with catheterization of the left vertebral artery, B: Virtual flow tracking of the left vertebral artery: the posterior cerebral artery (orange) is an arterial feeder, C: Virtual MR cartography of the arterial feeders: posterior meningeal artery (violet), middle meningeal artery (red), D: Virtual MR cartography of the entire DAVF: arteriovenous shunt (blue), venous drainage (green).

Discussion:

We present here a novel post-processing procedure applied to 4D MR Flow imaging, allowing for the first time to obtain a non-invasive selective cartography of AVMs and DAVFs. For very complex vascular structures like AVMs, this color-coded cartography greatly simplifies the visualization and the understanding of the malformation. In DAVFs, the good-to-excellent agreement between virtual catheter-based MR cartography and DSA findings suggests that it is a reliable tool for the identification and characterization of intracranial DAVFs with respect to the fistula site, venous drainage types, main arterial feeders and Cognard classification.

The main limitation of this procedure is the lack of sensitivity to clearly depict small vascular structures such as thin arterial feeders (tentorial artery or transosseous arteries) and AVMs nidus. It is noteworthy that, this selective MR cartography method is not captive with a dedicated MR pulse sequence and could benefit from the higher spatial resolution provided by recent technical MR advances.

Conclusion:

Virtual catheter-based MR cartography is a promising alternative to DSA in the diagnosis and follow-up of brain vascular malformations. In the case of DAVFs in particular, selective MR cartography could replace DSA in the prediction of rupture risk and therapeutic decision, thanks to its ability to obtain an MR Cognard classification.

References: [1] Farb B et al., AJNR, 30:1710-14, 2009; [2] Jagadeesan B et al., Stroke, 42:87-92, 2011; [3] Hodel J et al., AJNR, 32:196-7, 2011; [4] Hope MD et al., AJNR, 30:362-6, 2009; [5] Gu T et al., AJNR, 26 :743-9, 2005 ; [6] Cognard C et al., Radiology, 194 :671-80, 1995.