Characterising Congenital Vascular Malformations using MR-Based Data

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Introduction

Artero-venous malformations (AVMs) are high-flow congenital defects in the vascular system, consisting of tangles of abnormal blood vessels in which the feeding arteries are directly connected to a venous drainage network. The main challenge for achieving an effective treatment of this pathology is to make a correct diagnosis, identifying the AVM type based on its morphology. A computational model using the Contrast Agent (CA) information from 2D X-rays (DSA) data [2] was developed to classify AVMs.
Because of the non-ionising radiation and thanks to recent technical developments in magnetic resonance imaging (MRI), we hypothesise that we can classify AVMs informing such computational tool with 3D dynamic MRI data.

Materials and Methods

The dataset consists of 9 time-resolved Contrast-Enhanced MR Angiography (CE-trMRA) scans of AVMs in the extremities.
An algorithm was developed in MATLAB for the computation and representation of diagnostic parameters to aid in the classification of pAVM.
The preprocessing involves a series of temporal and spatial median filters, followed by the application of a vessel detection algorithm based on the standard deviation values of the intensity for each voxel over time.
The diagnostic parameters calculated for each voxel include CA time of arrival (CA_{ToA}), CA dispersive maximum upslope and minimum downslope (CAsi and CAsd), and CA time of stay in a specific region.
In particular, CA_{ToA} is determined as the time elapsed between injection start at the inlet and the instant when a percentage of the local peak CA concentration value is reached in each voxel.
CAsi is determined by calculating the maximum time derivative of the CA spread in each pixel/voxel using finite differences.

$$CA_{si} = \left(\frac{c(i,t+\Delta t)-c(i,t)}{\Delta t}\right)_{max}$$

The diagnostic parameters are displayed on 3D colour maps and histograms.
For distinguishing the AVMs involving the microcirculation (type IV and CV-AVM), a second algorithm was developed, which identifies the dispersivity of veins and arteries through the placement of Regions of Interest (ROIs) and plots their concentration curves.

Results

3D CA_{ToA} colormaps allow a visualization of the predominant aspects of the AVM. These may support clinicians in the navigation in the AVMs and in locating feeding and draining patterns to and from the nidus. CA_{ToA} histograms of type II, III and IV AVMs are in agreement with the DSA patterns and known hemodynamic behaviour of the lesions. CV-AVM CA_{ToA} histograms stand out from other AVM types with non-zero values extending beyond 40 seconds, representing the distinctive late venous drainage. This trend is confirmed by the second algorithm.

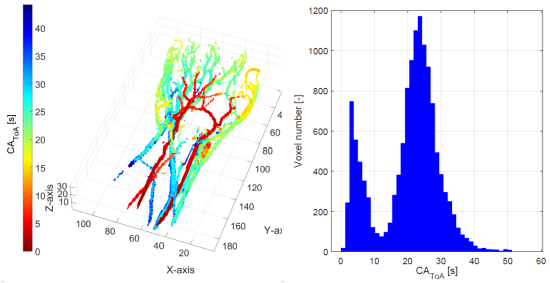

Fig. 1: Representative example of CA_{ToA} spatial distribution (left) and associated histogram representation (right) of a type IIIb AVM from MR data.

Discussion

The computational framework has a potential to become a diagnostic tool for navigation and classification of AVMs for clinicians. Unlike DSA, MRI allows CV-AVM to be distinguished from other AVM types in 3D CA_{ToA} histograms, thanks to its longer acquisition time. The MR slice thickness and the temporal resolution play a keyhole for an efficient AVMs characterisation, especially for type II and CV-AVM which have the smallest tangles of vessels. More datasets in anatomical regions other than extremities are needed to validate the preliminary results and more hemodynamic markers are under investigation.

References

[1] Frey S, Haine A, Kammer R, von Tengg-Kobligk H,ObristD, Baumgartner I. Hemodynamic Characterization of Peripheral Arterio-venous Malformations. Ann Biomed Eng. 2017 Jun;45(6):1449-1461. doi: 10.1007/s10439-017-1821-9. Epub 2017 Mar 21. PMID: 28324193.

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