3D PC VIPR pulse sequences with two encoding velocities: preliminary results in brain vascular disorders

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Introduction

Detailed evaluation of feeding arteries, nidus and venous drainage of arterio-venous malformations (AVM) is important for diagnostic, prognostic purposes and therapeutic decision [1]. However, arterio-venous brain disorders are complex three dimensional structures with thin vascular capillaries. A good spatial resolution and distinction of different vessel types (high or slow flows) are therefore needed for a comprehensive approach of these complex lesions with non-invasive imaging tools.

The 3D Phase Contrast Vastly Undersampled Isotropic Projection (PC VIPR) pulse sequence allows to measure quantitative flow dynamics with high isotropic spatial resolution in a short acquisition time [2]. The choice of encoding velocity (Venc), which determines the maximum measurable velocity, is a trade-off between noise performance and the highest speed one could measure**.** In this preliminary study, we assessed the clinical usefulness of PC VIPR images acquired with two different Venc settings, weighted either to slow (Venc=30cm/s) or to high blood flow velocities (80 cm/s) in two patients with brain vascular disorders.

Methods

Patients. Two patients with two types of brain vascular disorders (an arterio-venous malformation with a venous intranidal ectasia (AVM) and a dural arterio-venous fistula) were prospectively imaged after institutional Review Board approval. The AVM was imaged before treatment, and two months after endovascular exclusion of ectasic pouch.

Acquisition. Following contrast injection of 15 mL of Gd-DTPA, velocity-encoded MR data were acquired using the 3D PC VIPR pulse sequence with retrospective cardiac gating [2] on a 3T MR scanner (GE Healthcare) with two acquisitions corresponding to two encoding speeds: one of 80 cm/s ($Venc_{80}$) and one of 30 cm/s ($Venc_{30}$). The imaging parameters were: FOV=22×22×22 cm^3, TR/TE = 6,6/2,8 ms, BW = 83.3 kHz, 16 000 radial projections with 256 readout points, leading to an acquired isotropic spatial resolution of 0.85×0.85×0.85 mm^3. The total scan time was about 9 minutes.

MR reconstruction and post-processing. For each encoding speed, 3D velocity maps and a segmentation of vessel boundaries were reconstructed from PC VIPR data using respectively phase- and complex-difference image as previously described [2]. 3D visualization and quantitative velocity measurements were performed using a commercial software (Ensight, CEI, Apex, NC).

Results and Discussion

In the two cases, PC VIPR data were informative and the two encoding speeds provided complementary information. $Venc_{30}$ data allowed the visualization of slow vascular compartments, including all normal and abnormal veins and nidus but, as expected, did not allow visualizing the arterial compartment. $Venc_{80}$ data allowed the visualization of intracranial arteries, enabling quantitative velocity measurements in the feeding artery in the two studied cases.

In the patient with AVM, $Venc_{30}$ data provided vessel segmentation that allowed detecting a 4-mm venous ectasia (Fig.1a-b) before selective treatment that was no longer visible on post-treatment acquisition. In addition, $Venc_{80}$ data detected changes in velocity after treatment on one of the feeding arteries (Fig.1c).

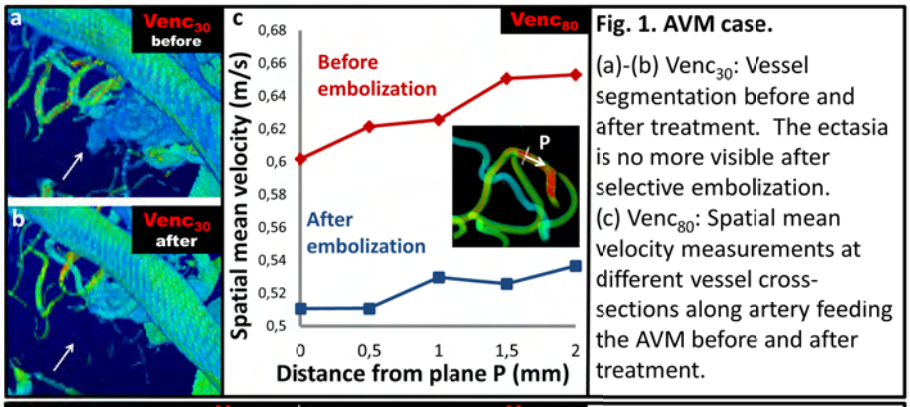

Fig. 1. AVM case.

(a)-(b) $Venc_{30}$: Vessel segmentation before and after treatment. The ectasia is no more visible after selective embolization. (c) $Venc_{80}$: Spatial mean velocity measurements at different vessel cross-sections along artery feeding the AVM before and after treatment.

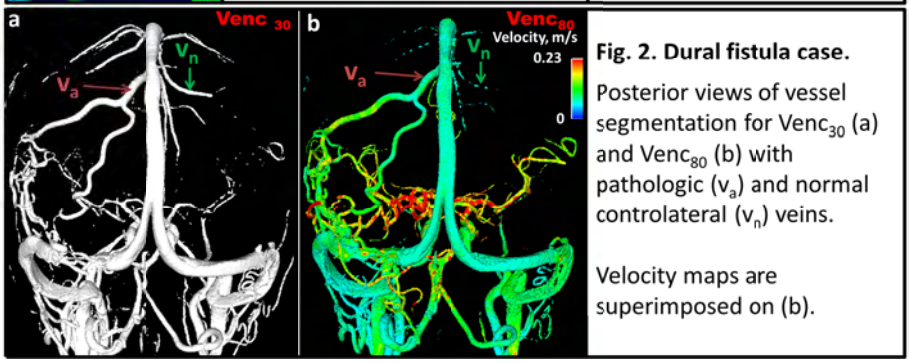

Fig. 2. Dural fistula case.

Posterior views of vessel segmentation for $Venc_{30}$ (a) and $Venc_{80}$ (b) with pathologic (v_a) and normal controlateral (v_n) veins.

Velocity maps are superimposed on (b).

In the patient with dural fistula, $Venc_{30}$ and $Venc_{80}$ both showed abnormal cortical veins draining the fistula (v_a in Fig.2), although $Venc_{30}$ provided a better segmentation of normal contralateral veins than $Venc_{80}$ (v_n in Fig.2a-b). Furthermore, $Venc_{30}$ identified an accelerated velocity (14 cm/s) in the abnormal cortical vein compared to that in the contralateral normal veins (5 cm/s). Using $Venc_{80}$, arterial feeders of the fistula were better visualized than using $Venc_{30}$ (Fig.2b) and velocity measurements showed slightly accelerated velocity (36 cm/s) in feeding arteries compared to the contralateral side (34 cm/s) in line with a previous report [3].

This preliminary study illustrates, for two brain vascular disorders, the potential benefit of the use of two encoding speed acquisitions, which provides complementary quantitative and qualitative information.

When sensitize to slow flow motions ($Venc_{30}$), PC VIPR was able to distinguish small intranidal structures such as small venous ectasia, which is crucial for the diagnostic and prognostic of rupture risk. Moreover, velocity measurements helped to point out abnormal vessels, presenting a higher speed than the contralateral side. This is of importance for the longitudinal follow-up after treatment.

The main limitation of the technique is the long reconstruction and post-processing time since each process is adapted according to the pathology location and extent specific for each patient. Moreover, the use of two encoding speeds doubles the scan time. In the future, it would be very useful, especially in clinical routines, to use novel techniques of flow encoding reducing the acquisition time, such as the Five-Point balanced flow encoding method [4] or accelerated dual Venc imaging [5].

Conclusion

Having a complete intracranial arterial and venous coverage of the pattern and distribution of flow will help to assess precisely the diagnostic of complex vascular lesions, and quantitative analysis of blood flow will provide with a new tool for the pre and post therapeutic monitoring. Future work includes analyzing more clinical cases of AVM and fistulas and longer longitudinal follow-up.

References

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