Non-contrast-enhanced high-temporal-resolution 4D MRA with an acquisition window covering two cardiac cycles: Assessment of arteriovenous malformations in the brain

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Target audience : neuroradiologists, MR physicists

Purpose

Non-contrast-enhanced ECG-gated 4D MRA combining arterial spin labeling (ASL) and bSSFP readout (bSSFP NCE 4D MRA) enables non-invasive investigation of morphological and hemodynamic patterns of cerebral arteriovenous malformations (AVM)[1,2]. Previous studies have shown high temporal resolution (50-100 ms), yet with temporal windows limited to a single cardiac cycle[1,2,3]. This precludes the complete venous drainage analysis, which is necessary to evaluate AVM hemorrhagic risk. This study aimed at assessing the feasibility, quality and diagnosis performance of a bSSFP NCE 4D MRA sequence with a large acquisition time window over 2 cardiac cycles (2 RR) without a significant reduction of spatial resolution.

Methods

After approval from the Institutional Review Board, ten patients presenting AVM and referred to digital subtraction angiography (DSA) were included in the study. Patients underwent NCE 4D MRA on a 3T system (MAGNETOM Verio, Siemens Healthcare), using a 32-ch head array coil. The NCE 4D MRA technique combined ASL (subtraction of data acquired with inferior inversion band from control data) with an ECG-triggered 3D cine segmented multiphase bSSFP readout. Imaging parameters for 2-RR NCE 4D MRA were: FOV=220x192mm2, 44 slices, 1.5x1.5x1.5mm3 voxel size, TR/TE=59.5ms/2.13ms, variable flip angle evolution (continuously increasing from 12° to 45° according to a parabolic function throughout the acquisition), mSENSE 2 and 14 segments to achieve a temporal resolution of 61 to 71 ms. Acquisition time ranged between 10 and 12 minutes, depending on patient heart rate. For 1-RR NCE 4D MRA, 64 slices achieved similar coverage with a 1x1x1mm^3 voxel size within 5 to 6 minutes. Other sequences performed were: TOF MRA (TR/TE=20ms/3.19ms, voxel size=0.7x0.6x0.6mm^3) and 4D CE-MRA (TR/TE=3ms/1.14ms, 0.9x0.8x1.5mm^3 voxel size, GRAPPA 3, 1.5s temporal resolution). All patients also underwent DSA with a filming rate of 4 images/s. Images were reviewed with respect to image quality and AVM diagnosis value.

Results

Both NCE 4D MRA sequences were successfully performed in all patients (table 1) achieving high image quality. All AVM were depicted with their main feeding arteries and global nidus size in agreement with DSA data (fig.1). Venous drainage type was always correctly classified on 2-RR NCE 4D MRA images, but misidentified in five cases on 1-RR NCE 4D MRA. The 2-RR NCE 4D MRA allowed a more accurate delineation of the nidus than combined TOF and CE 4D MRA data, with diagnosis confidence index (DCI)[2] higher than TOF for venous drainage (1.1 (±0.8)) and CE 4D MRA for feeding arteries (3.0 (±0.7)).

	n phases	Temporal resolution	Acquisition time window	Overall quality	DCI for feeding arteries	DCI for nidus size	DCI for venous drainage
1 RR NCE MRA	10 - 16	62 - 78 ms	706 - 1250 ms	3.3 (±0.8)	4.2 (±0.8)	4.2 (±1.3)	2.0 (±1.3)
2 RR NCE MRA	20 - 32	61 - 71 ms	1412 - 2182 ms	3.9 (±0.6)	3.6 (±0.7)	4.4 (±0.7)	3.8 (±0.9)

Table 1. Comparison between 1- and 2-RR NCE 4D MRA: temporal parameters and DCI (1: bad to 5: excellent)

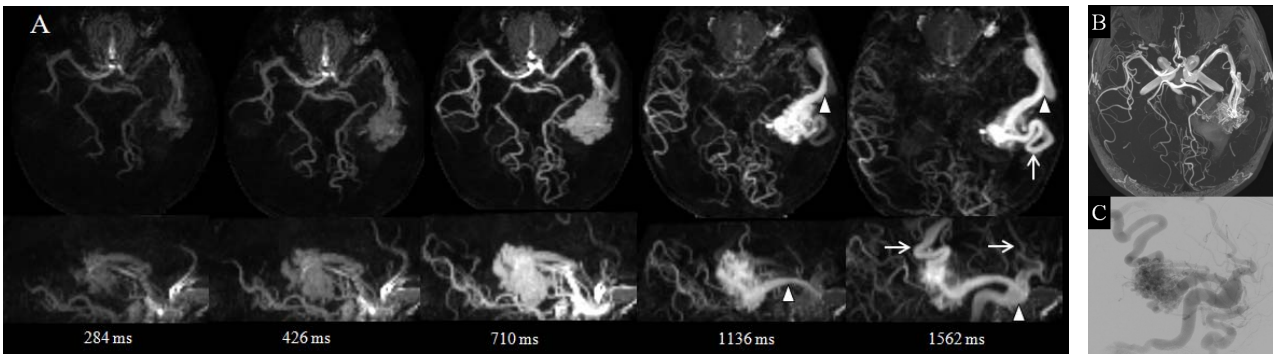

Figure 1. 2-RR NCE 4D MRA in axial (top) and sagittal (bottom) planes showing two draining veins into the superior sagittal sinus (arrows) and an earlier drainage into the left lateral sinus (arrowhead). Corresponding TOF (B) and DSA (C).

Discussion and Conclusion

The 2-RR bSSFP NCE 4D MRA sequence yielded an image quality comparable to that of a corresponding 1-RR acquisition. AVM analysis, however, was improved due to a better depiction of venous drainage [1,2], necessary to evaluate hemorrhagic risk. The simultaneous high-resolution morphologic and hemodynamic data also offered an especially accurate delineation of the nidus, target of the treatment.

References : 1. Xu J, Shi D, Chen C, et al. JMRI 2011; 34(5): 1199-205
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3. Lanzman RS, Kröpil P, Schmitt P, et al. Eur Radiol 2011; 21(6) :1329-1338