4D Flow MRI for intracranial hemodynamic assessment in Alzheimer's Disease

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Target Audience: Researchers and clinicians interested in MR flow imaging, hemodynamic biomarkers, and dementia.

Purpose: There is increasing evidence that cerebral arteries are often morphologically altered and dysfunctional in Alzheimer's disease (AD) [1]. Therefore, there is growing interest in the non-invasive assessment of cranial hemodynamics as potential systemic indicators of AD [2]. Recent advances in MR hardware, data acquisition, and reconstruction have facilitated 4D flow MRI in clinically feasible scan times, thereby providing dynamic velocity vector maps with volumetric coverage. With adequate spatial and temporal resolution, such 4D flow MRI approaches seem ideally suited for comprehensive hemodynamic assessment. In this study, we investigated intra-cranial flow features; particularly mean flow, pulsatility index and lumen area in patients with AD, mild cognitive impairment (MCI) and in healthy controls.

Methods: ***Subjects***: The study population consisted of 36 AD patients (age 57-91y, mean=72.6, 13 F), 42 MCI patients (age 52-87y, mean=73.1, 17 F), 56 normal old (age 63-89y, mean=73.6, 34 F) and 173 normal middle age (age 43-62y, mean=57.1y, 123 F). With IRB approval and HIPAA compliance, informed consent was obtained for all study subjects. ***MRI****:* Volumetric, time-resolved PC MRI data with 3-directional velocity encoding were acquired on a 3T clinical MRI system (MR750, GE Healthcare,) with a 3D radially undersampled sequence, PC VIPR [3] with the following imaging parameters V_{enc} = 80 cm/s, imaging volume = 22x22x11 cm^3, (0.7 $mm)^3$ acquired isotropic spatial resolution, TR/TE=7.4/2.7ms, scan time ~ 7 min, retrospective cardiac gating into 20 cardiac phases with temporal interpolation[4]. ***Flow analysis:*** Vessel segmentation was performed in Matlab (The Mathworks, Natick, MA) from PC angiograms generated from the 4D flow MRI data while flow visualization and quantification was performed in EnSight (CEI, Apex, NC). Flow analysis planes were interactively placed orthogonal to the vessel orientation in 11 locations as shown in Fig. 1: internal carotid arteries, the basilar artery the, middle cerebral arteries and posterior cerebral arteries. 2D planes through each vessel segment were generated from the 4D flow MRI data and analyzed in a customized Matlab analysis tool [5]. Mean flow, pulsatility index (PI = (Qmax-Qmin/Qmean)) and lumen area were calculated for all vessel segments and groups were compared with Student's t-test (statistical significance for $p<0.05$). Anatomical variants of the Circle of Willis were cataloged into four groups according to [6]: textbook, P1 hypoplasia, A1 hypoplasia and other.

Results and Discussion: Results for the analysis are summarized for all 11 vessel locations (left & right) in Figures 2 & 3. There is statistically significant difference in mean flow and PI between all groups for each segment except those marked with an 'x' (4 pairs for mean flow and 8 pairs for PI). Statistically significant differences on lumen area were also found for most the groups (20 pairs with significant differences, 16 pairs without significant differences). These results are similar to those reported in a study based on intracranial ultrasound and are thought to be a consequence of increased arterial rigidity and decreased arterial compliance combined with age-associated cardiovascular output declines [2]. The final count of anatomical variants was: 205 textbook, 56 P1 hypoplasia, 18 A1 hypoplasia and 28 other.

Conclusions: This study demonstrates the feasibility of hemodynamic analysis over a large vascular territory in the context of Alzheimer's disease with 4D flow MRI within a 7 minute acquisition. Significant differences were demonstrated in the PI, mean flow and lumen area between AD and MCI patients and a normal control group in most vessel segments. The brain stem and cerebellum are not significantly involved in AD and MCI possibly accounting for the lack of statistical significance difference in the basilar artery parameters. With the large volume coverage and high temporal and spatial resolution demonstrated here, 4D flow MRI can provide additional biomarkers of vascular health that can contribute to identifying patients who could benefit from interventions to improve circulatory system functions.

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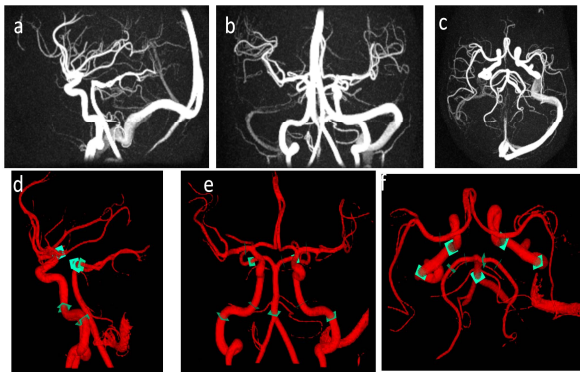

Figure 1: PC VIPR data shown as(a) sagittal, (b) coronal, and (c) axial MIP image of the PC angiogram and corresponding view of the segmented arteries with eleven flow analysis planes placed perpendicular to the vessel path (d,e,f).

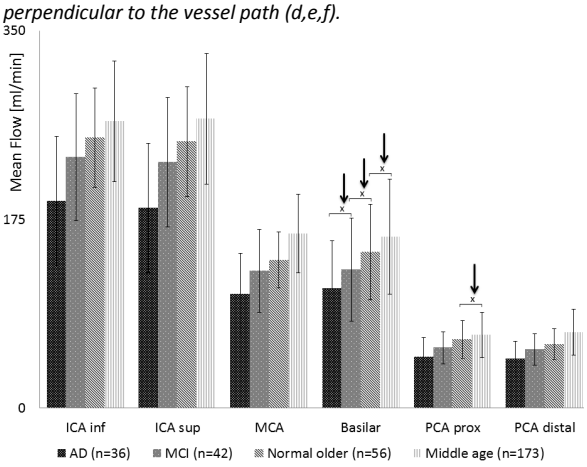

Fig 2: Mean flow (mL/min) for patients with Alzheimer's disease (AD), Mild Cognitive Impairment (MCI) and the normal control group. Left and right branches are reported together. For each vessel segment, the mean flow is statistically different among all cohorts, with exception of the 4 pairs indicated with an 'x'.arrows

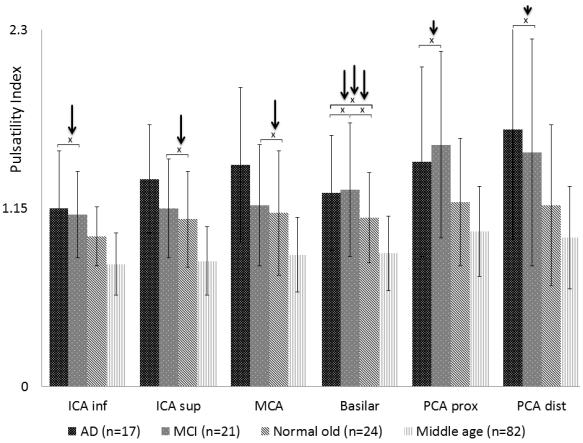

Fig 3: Pulsatility index. No statistical significance was found on the groups marked with an 'x'.arrows