

Aortic Stiffness, Cerebral Hemodynamics, And White Matter Hyperintensity Volume Within Vascular Territories Using Heart-Brain MRI

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Take-Home Message: We present a heart-brain MRI protocol to investigate potential mechanisms linking aortic stiffness to markers of brain injury in aging adults with and without hypertension. Aortic stiffness was associated with WMH independent of age in hypertension. The absence of this association in healthy controls may reflect a later stage of vascular injury in hypertension. Aortic stiffness was also related to increased Circle of Willis resistivity, supporting further investigation of its potential contribution in a larger sample.

Background

Arterial stiffening has been linked with age, hypertension, markers of brain injury, including white matter hyperintensities (WMHs), and cognitive decline. However, the underlying hemodynamic relationships along the heart-brain pathway remain unclear¹⁻². 4D flow MRI³⁻⁴ is a powerful tool for quantifying hemodynamic parameters in major blood vessels.

Objective: We developed a comprehensive heart-brain MRI protocol and analysis workflow using 4D flow and structural brain MRI and investigated associations between aortic stiffness, cerebral hemodynamics, and WMH within vascular territories.

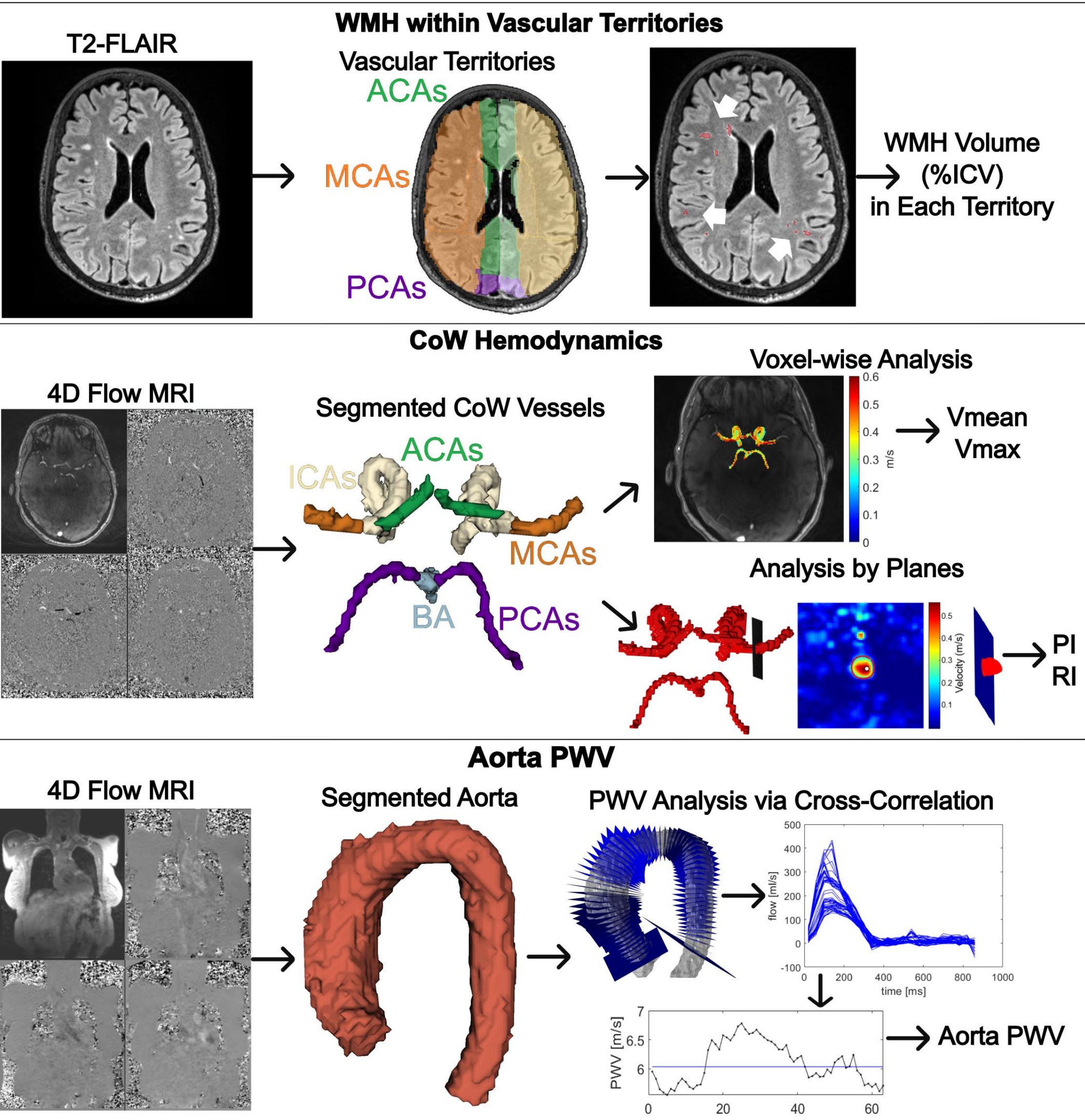
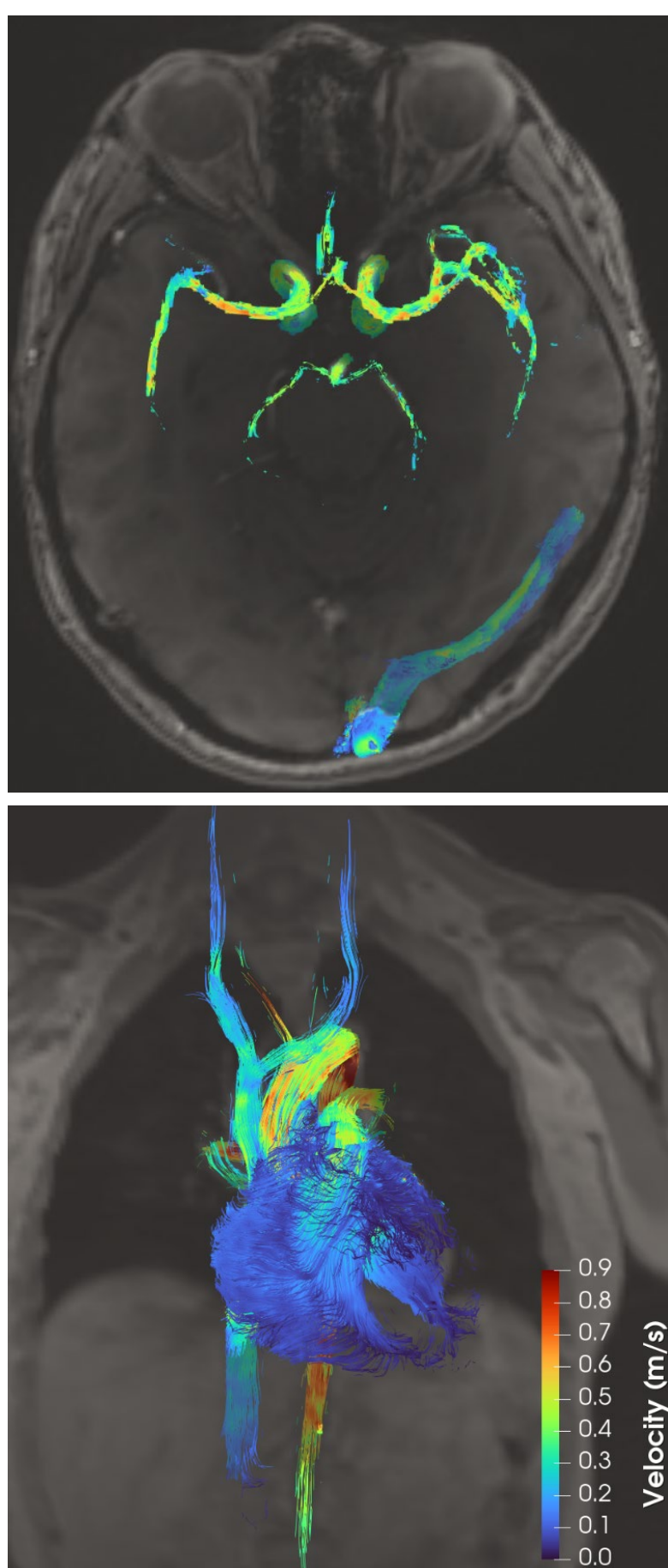


Figure 1. Heart-brain MRI acquisition and analysis workflow.

Methods

Cohort: 49 cognitively asymptomatic adults (T-MoCA $\geq$ 17) with and without hypertension:

- Age: 63.1 $\pm$ 8.0 [49-78] years; 33 females
- 21 with hypertension (HTN) and 28 healthy controls

Imaging Protocol (3T, MAGNETOM Prisma, Siemens):

- T1-MPRAGE and T2-FLAIR
- Intracranial 4D flow MRI
- Whole-heart 4D flow MRI

Quantifications:

WMH volume (%ICV) within vascular territories⁵

Circle of Willis (CoW) hemodynamic parameters:

- Mean (Vmean) and peak systolic velocity (Vmax, m/s)⁶
- Pulsatility index (PI): $(\text{flow}_{\text{max}} - \text{flow}_{\text{min}}) / \text{flow}_{\text{mean}}$ ⁷
- Resistivity index (RI): $(\text{flow}_{\text{max}} - \text{flow}_{\text{min}}) / \text{flow}_{\text{max}}$ ⁷

Pulse wave velocity (PWV) of the thoracic aorta⁸.

Results

Participants with HTN were older (66.0 $\pm$ 8.1 vs 61.0 $\pm$ 7.4, p=0.03), had $\uparrow$ CoW PI (1.18 $\pm$ 0.22 vs 1.04 $\pm$ 0.14, p=0.007[age adjusted p=0.06]) and $\uparrow$ RI (0.71 $\pm$ 0.08 vs 0.66 $\pm$ 0.06, p=0.02[p=0.19])

All Participants: Age correlated with $\uparrow$ aorta PWV, $\uparrow$ CoW RI, and $\uparrow$ total WMH. Aorta PWV correlated with $\uparrow$ CoW RI and $\uparrow$ total WMH. CoW RI showed a trend with WMH (r=0.28, p=0.056).

Hypertensive Participants: Aortic PWV correlated with $\uparrow$ total WMH and remained significant after adjusting for age (p=0.016).

Figure 2 summarizes the regional correlations along the heart-brain pathway in all participants and subgroups.

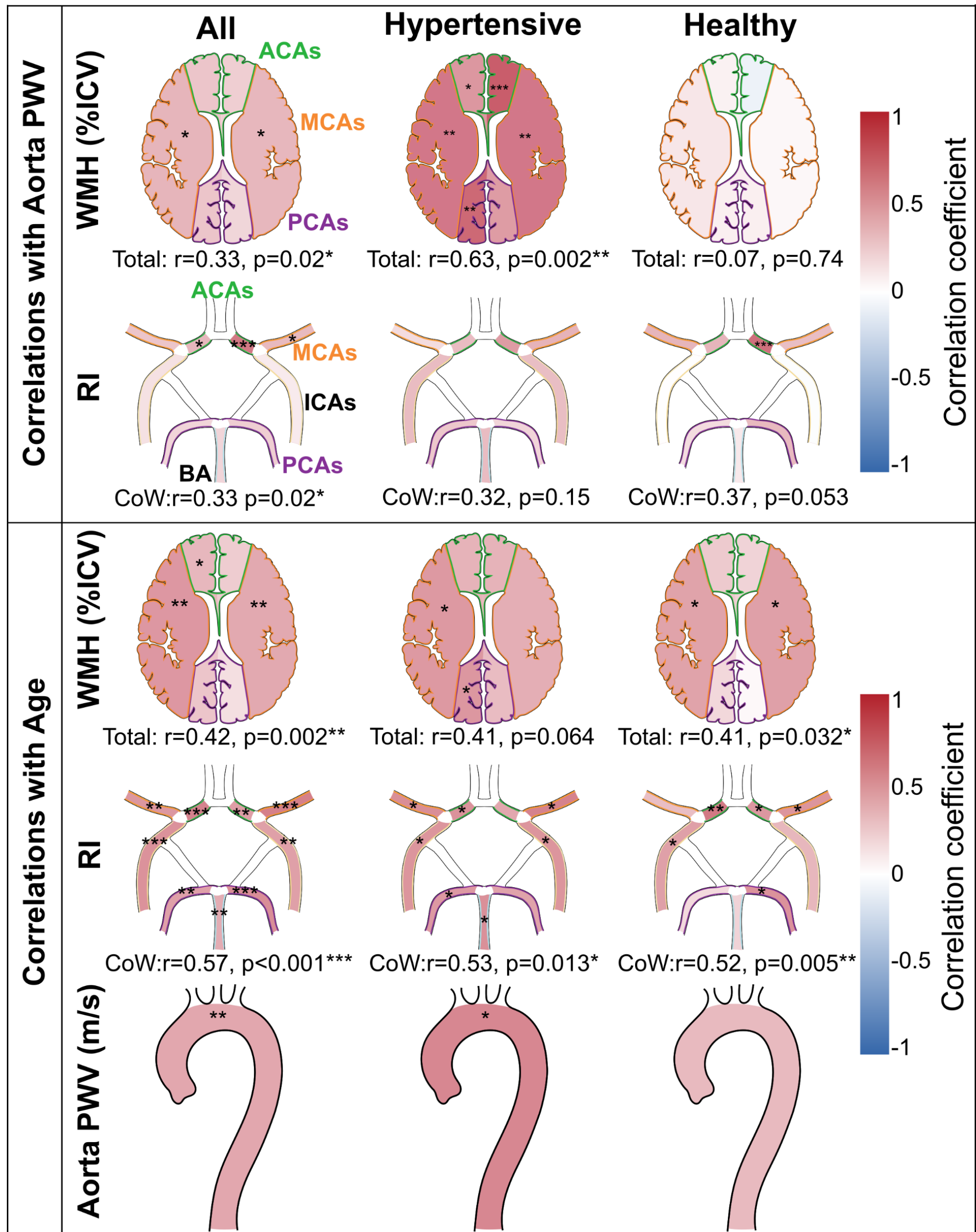


Figure 2. Regional correlations with age and aorta PWV
.*p<0.05, **p<0.01, ***p<0.001

Conclusions

Aorta PWV-WMH relationship in line with literature¹⁻². Aorta PWV-WMH correlation in hypertension independent of age supports a **potential hemodynamic mechanism**. Absence of this association in healthy controls may be due to later-stage vascular injury continuum with overt WMH in hypertension. PWV-CoW RI association, as well as CoW RI trend with WMH in the cohort support investigating potential mediation.

Next steps: Investigating DTI markers of earlier-stage WM injury and applying this method in cognitive impairment.

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