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An automated tool for vascular and perivascular segmentation of brain MRI data to identify the risk of dementia and accelerated brain atrophy

Stanford scientists have developed PVSeg, a tool that automatically segments vascular and perivascular compartments in brain MRI data. This innovative tool can identify non-demented individuals at increased risk of developing dementia and accelerated brain atrophy. PVSeg's metrics could serve as a screening tool, allowing early diagnosis of brain microvascular issues and potentially improving patient treatments and outcomes. Additionally, it could enrich clinical trials for treatments targeting cognitive decline by identifying suitable candidates at increased risk of future cognitive impairment, thereby reducing subject enrollment challenges and decreasing costs. Moreover, in clinical trials specifically targeting Alzheimer's disease pathology (amyloid-β and tau), PVSeg's metrics can refine the selection of participants with a "purer" form of preclinical Alzheimer's disease by identifying and screening out individuals with radiographic signs of vascular damage, improving efficiency and effectiveness of clinical trials for Alzheimer's disease. Finally, PVSeg's metrics are suitable for longitudinal assessments, allowing the evaluation of treatment effects on the brain vasculature *in-vivo*.

Cerebral small vessel disease is a significant contributor to cognitive decline and dementia. Currently, clinicians use magnetic resonance imaging (MRI) to detect signs of vascular damage in the brain, such as white matter hyperintensities and microbleeds. However, these markers are often subtle in healthy individuals and lack quantitative precision. Recent advancements allow for the measurement of brain vasculature and perivascular spaces using standard T1-weighted MRI scans.

Yet, current techniques have notable limitations: they are user-dependent, leading to potential inconsistencies, and lack inter-scanner reproducibility. These drawbacks hinder the execution of large-scale, longitudinal studies and clinical trials crucial for understanding the relationship between vascular changes and cognitive impairment over time. There is a clear need for a more robust, automated method to quantify cerebral vascular structures consistently across different MRI machines and over extended periods.

A novel, fully automated algorithm has been developed to assess perivascular diameter and count of blood vessels with MRI-visible perivascular space in white matter and basal ganglia using standard 3D T1-weighted MRI scans. PVSeg demonstrates excellent inter-scanner and test-retest reproducibility, addressing key limitations of current methods. Importantly, the algorithm revealed significant associations between vascular metrics and dementia risk, as well as brain atrophy rates, in a large-scale study (>10,000 subjects). By enabling more efficient screening in clinical trials, PVSeg has the potential to substantially reduce required participant numbers and to refine their selection, thereby increasing trial power and reducing costs in dementia research.

Stage of Development:

- Preclinical *in-vivo*
- Continued research - Further clinical applications of the algorithm are currently being explored at Stanford.

Applications

- Assessment of cerebral small vessel disease and its relation to cognitive decline
- Early detection of individuals at high risk for dementia
- Enrichment of clinical trials for cognitive impairment and dementia
- Evaluation of treatment effects on brain vasculature *in-vivo*

Advantages

- Fully automated segmentation of vascular and perivascular compartments in brain MRI

- Excellent inter-scanner reproducibility and test-retest repeatability
- Robust performance in longitudinal studies
- Requires only standard T1-weighted MRI sequences, enabling widespread use
- Potential for significant cost reduction in clinical trials through improved participant selection

Publications

- Barisano, Guiseppe, et al. Robust, fully-automated assessment of cerebral perivascular spaces and white matter lesions: a multicentre MRI longitudinal study of their evolution and association with risk of dementia and accelerated brain atrophy. *eBioMedicine: Part of THE LANCET Discovery Science,* January, 2025.

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