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Vessel Wall Remodeling Index and Pathologic Plaque Burden as Quantitative Markers to Differentiate Intracranial Arterial Pathologies in High-Resolution Vessel Wall MRI

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Purpose

High-resolution vessel wall MRI (HR-VWI) provides detailed visualization of arterial wall pathology beyond luminal imaging. The purpose of this study was to assess quantitative parameters, specifically vessel wall remodeling and pathological wall burden, across major intracranial vasculopathies, and determine whether these parameters can help differentiate diseases that often appear similar on conventional luminal angiographic techniques such as CTA, MRA, or DSA.

Materials and Methods

A retrospective single-center study included 339 patients who underwent HR-VWI over seven years. After excluding suboptimal images, 179 patients (52.8%) were analyzed, and 84 (46.9%) were randomly selected for quantitative evaluation. Imaging was performed on 3T MRI scanners using pre- and post-contrast 3D turbo spin-echo sequences with isotropic 1 mm voxels. Curved multiplanar reconstructions were used to measure vessel and lumen areas at stenotic and reference sites. The remodeling index (RI) was defined as the ratio of stenotic to reference vessel area (positive >1.05, negative <0.95, absent 0.95–1.05). Pathologic wall burden was calculated as (stenotic wall area/stenotic vessel area) × 100. Two neuroradiologists, blinded to clinical information, reviewed qualitative features including enhancement, morphology, and mural hemorrhage. Statistical analyses used ANOVA, Kruskal-Wallis, and multivariate logistic regression to identify independent diagnostic predictors.

Results

Final diagnoses included intracranial atherosclerotic disease (ICAD, n=40), dissection (n=14), vasculitis (n=8), vasospasm (n=4), normal controls (n=10), and others (n=8). Positive remodeling occurred in 55% of ICAD, 86% of dissections, and 38% of vasculitis cases, while negative remodeling predominated in vasospasm (75%) and controls (80%) ($p<0.01$). Mean pathological wall burden was 71.9% ±20.8 in ICAD, 84% ±20.9 in dissection, 75.6% ±16.3 in vasculitis, and 30% ±20.7 in vasospasm ($p<0.01$). Wall enhancement occurred in 47.5% of ICAD (mostly eccentric) and 87.5% of vasculitis (concentric). Mural hemorrhage was present in 92.9% of dissections ($p<0.001$). Multivariate logistic regression identified plaque burden (OR 1.04; 95% CI 1.02–1.07; $p<0.001$) and mural hemorrhage (OR 0.04; 95% CI 0.01–0.20; $p<0.001$) as independent predictors of ICAD (AUC=0.82). For dissection, mural hemorrhage was the strongest predictor (OR 471.8; 95% CI 10.1–>999.9; AUC=0.94).

Conclusion

Quantitative HR-VWI parameters, particularly remodeling index and wall burden, effectively distinguish intracranial vascular pathologies. Distinct signatures were observed: positive remodeling and high burden in dissection, variable remodeling in ICAD, mixed remodeling with concentric enhancement in vasculitis, and low burden with absent remodeling in vasospasm. Combining these quantitative indices with qualitative features such as enhancement and mural hemorrhage increases diagnostic specificity and supports HR-VWI as a precision imaging tool for intracranial vascular disease evaluation.

References

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Figures

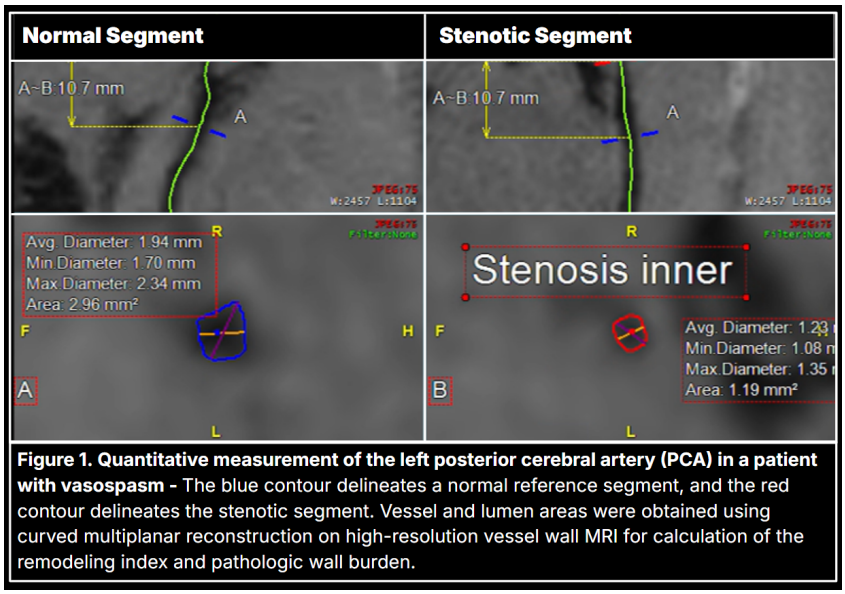

Figure 1. Quantitative measurement of the left posterior cerebral artery (PCA) in a patient with vasospasm - The blue contour delineates a normal reference segment, and the red contour delineates the stenotic segment. Vessel and lumen areas were obtained using curved multiplanar reconstruction on high-resolution vessel wall MRI for calculation of the remodeling index and pathologic wall burden.