UTILITY OF 7T MRI IN 2024 Mc DONALD CRITERIA FOR MULTIPLE SCLEROSIS

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Key Updates in the 2024 McDonald Criteria

- Expanded Dissemination in Space (DIS): Optic nerve officially added as the 5th anatomical location for DIS.
- Paraclinical Biomarkers: CSF kappa free light chains (kFLCs) recognized as equal alternative to Oligoclonal bands.
- RIS(Radiologically Isolated Syndrome) Inclusion: RIS can now be diagnosed as MS if DIS is accompanied by dissemination in time (DIT), CSF positivity, or >=6 central vein sign (CVS) lesions
- Age/Comorbidity Rules: Strongly mandates spinal cord lesion, CSF positivity, or >=6 CVS lesions for patients >50y or with vascular risk

Teaching Objectives

To focus on importance of

1. Superior visualization of susceptibility-based biomarkers with 7T

2. Doubling the diagnostic yield for cortical pathology using 7T

3. Precision diagnostics for complex cases by differentiating MS from mimics

Physical and Technical superiority of 7T

- SNR Boost: Field strength scaling from 3T to 7T increases signal-to-noise ratio by >2.3x.

- Susceptibility Enhancement: Magnetic susceptibility effects scale linearly with B0, multiplying T2* phase contrast.

- Ultra-High Spatial Resolution: Achieves sub-millimeter isotropic resolution (0.1 x 0.1 mm in-plane), resolving micro-vessels <0.5mm.

- Microvenule Conspicuity: Unmasks tiny intra-lesional medullary veins obscured by partial volume effects at 3T.

Physical and Technical Superiority of 7T

Technical Sequence Capabilities

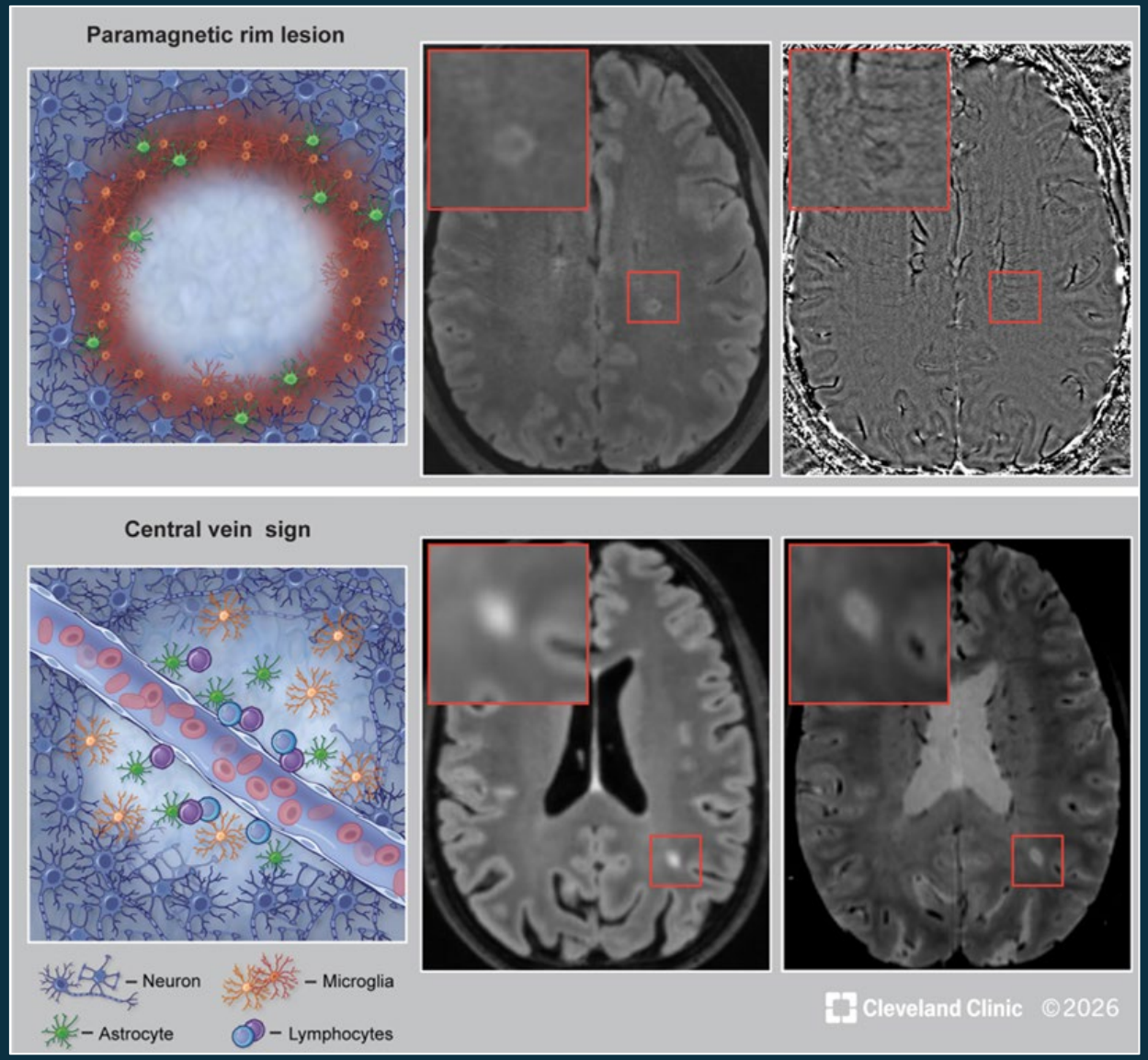
• 2D Gradient-Echo T2*WI: Configured with TE=20.8ms and high in-plane matrix, offering superior T2* weighting.

• 3D Susceptibility-Weighted Imaging (SWI): Provides high-contrast magnitude and phase maps for vein and rim visualization.

• 3D Double Inversion Recovery (DIR): Suppresses CSF and white matter signal to reveal cortical and optic nerve plaques.

• B1 Homogeneity Transmit Modes: Transmit coils overcome ultra-high-field RF dielectric artifacts.

Pathophysiology of Central Vein Sign and Paramagnetic Rim



Amin, M., Palmer, K.N., Samara, A. et al. Management of Multiple Sclerosis: Incorporating Recent Advances in Pathophysiology and Diagnosis to Guide Treatment Strategies. Drugs (2026).

Central Vein Sign (CVS) Inclusion Criteria

- Magnitude susceptibility-sensitive images
- Single thin (<2 mm) hypointense line or small hypointense dot
- Can be visualized in at least two perpendicular MRI planes
- Partly or entirely through the lesion
- Positioned centrally in the lesion

Exclusion criteria: lesion is <3 mm in diameter in all planes, confluent lesions, lesion has multiple distinct veins, or lesion is poorly visible

Perivenular Demyelination

Histopathological Basis of MS Demyelination

• Perivascular Origin: Autoimmune lymphocytic infiltration initiates around parenchymal venules (Dawson's perivenular model).

• Venous Anatomy: Primary inflammatory plaques develop around small medullary venules (<2mm diameter).

• Pathological Specificity: Perivenular demyelination is specific to MS and absent in ischemic leukoaraiosis or migraine.

• Ex Vivo Validation: Post-mortem 7T MRI confirms central venules in over 90% of histologically verified MS plaques.

In Vivo Visualization via Susceptibility MRI

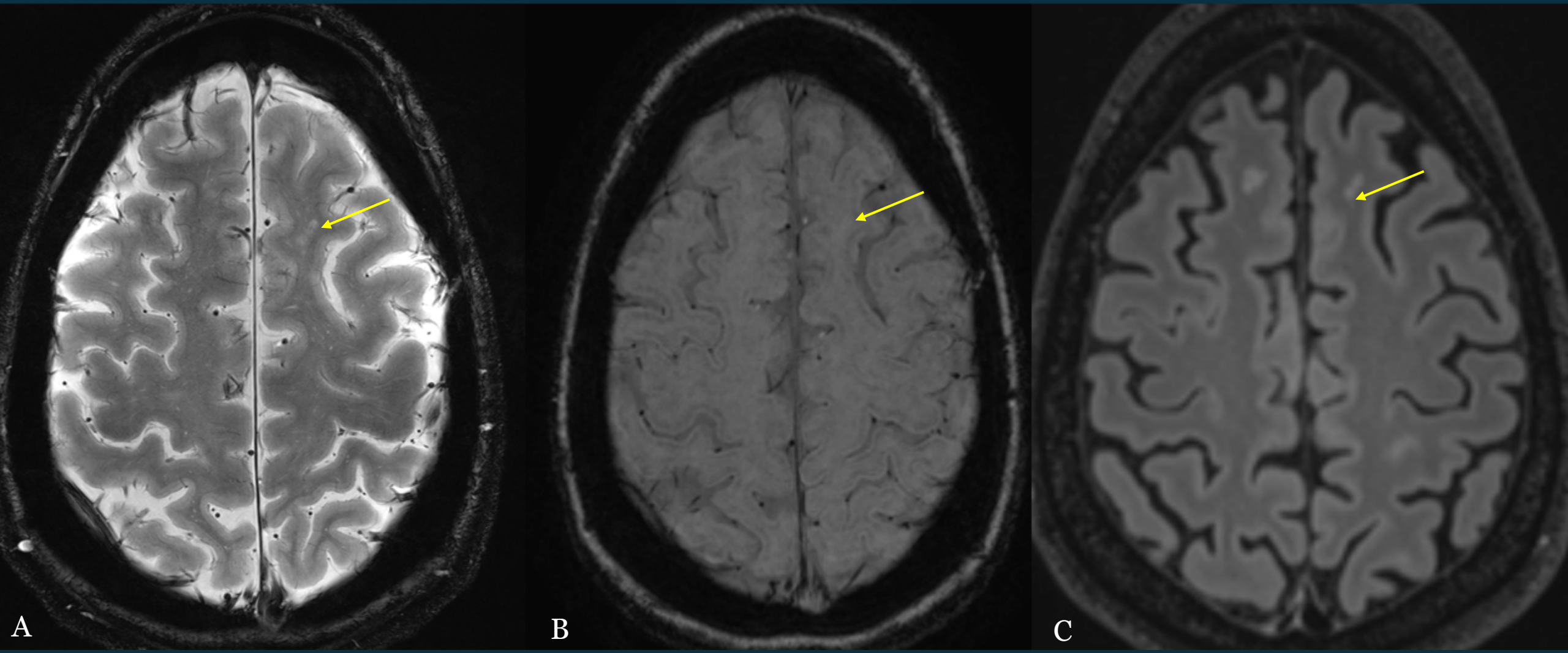
• Deoxyhemoglobin Effect: Intracranial veins contain paramagnetic deoxyhemoglobin, causing local T2* phase shift.

• Field Strength Scaling: Susceptibility-induced phase differences scale linearly with B0 field strength (7T vs 3T).

• Microvenule Resolution: Ultra-high field resolves sub-millimeter venules (0.1mm in-plane) that are invisible at lower field strengths.

• Diagnostic Transmutation: Converts a histological hallmark into a non-invasive radiologic biomarker.

Central Vein Sign (CVS)



CVS by MRI field strength. A, 7T T2* shows a central vein (arrow) that is not well seen on (B) 3T SWI which corresponds to a subcortical FLAIR hyperintensity (C) on 3T.

Paramagnetic Rim Sign Inclusion criteria

- Phase susceptibility-sensitive images
- Discrete rim with paramagnetic properties that is continuous around at least two-thirds of the outer edge of the white matter portion of the lesion
- Colocalizes with the edge of all or part of a lesion
- Rim is discernible on at least two consecutive slices (2D acquisition) or in two orthogonal planes (3D acquisition)
- T2-hyperintense lesion that does not enhance on T1 W post-gadolinium-based contrast agent images

Iron-Laden Microglial Rims

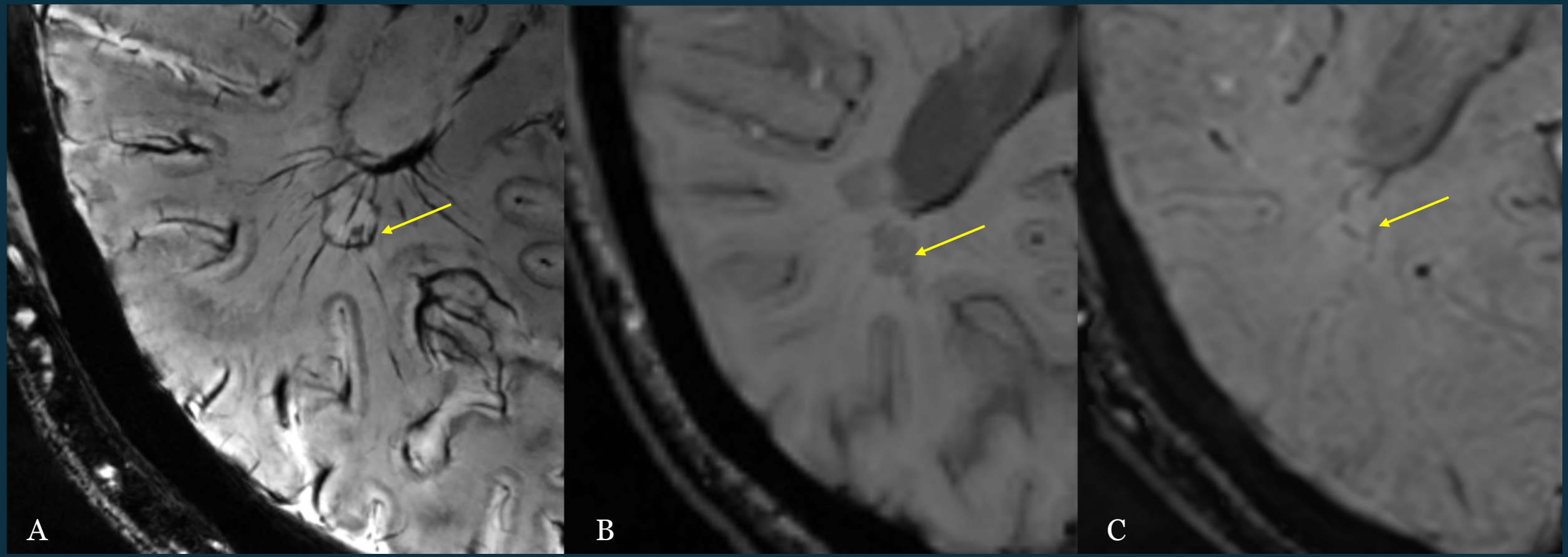
Histology & Imaging Morphology

- Chronic Active Lesions: Represents smoldering, slow-expanding demyelinating lesions with active edge microglial inflammation.
- Iron Microglia Rim: Hypointense paramagnetic rim on T2* phase/QSM images produced by iron-laden macrophages.
- Morphology Criteria: Discrete continuous rim covering >=2/3 of lesion perimeter on max visibility slice, seen on >=2 slices.
- Non-Enhancing Core: Core must be non-enhancing on post-contrast T1, confirming chronic rather than acute inflammation.

Clinical Prognosis & Diagnostic Utility

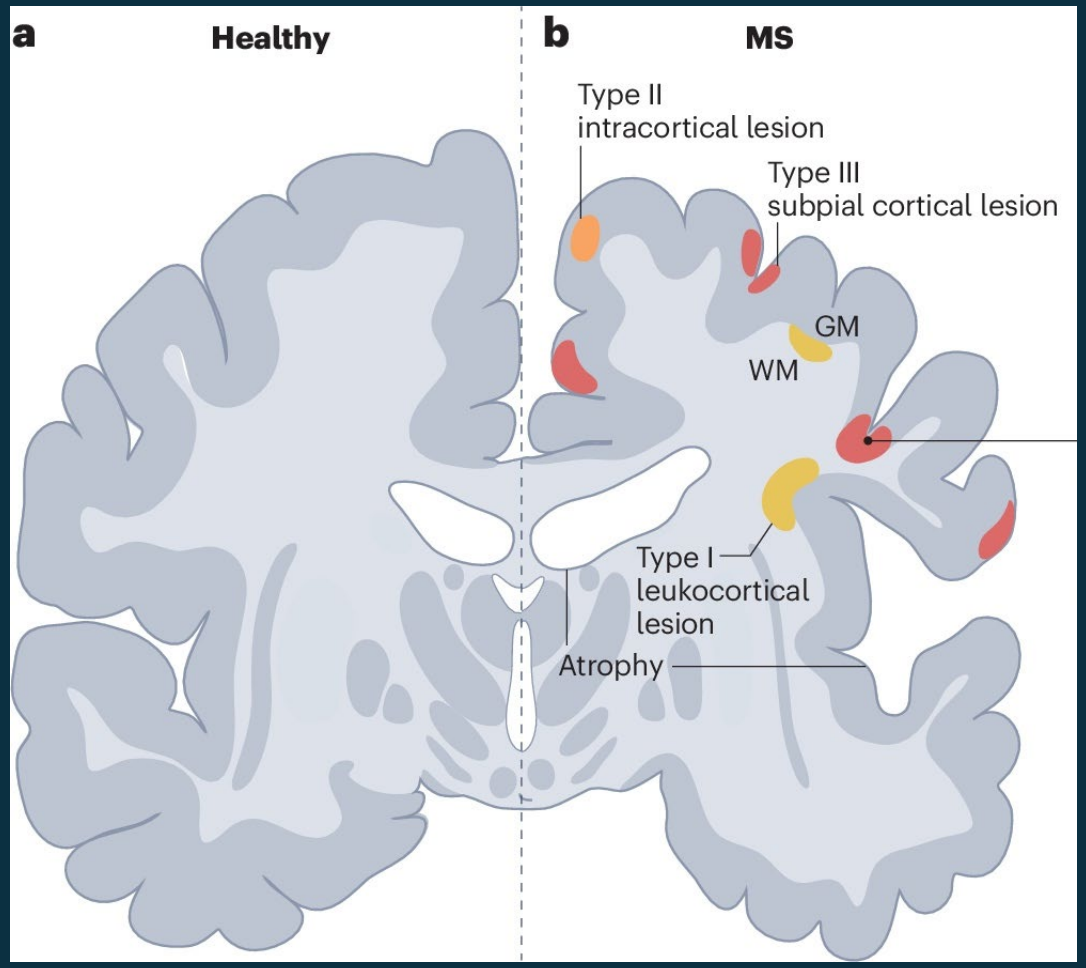
- Disability Predictor: Presence of >=1 PRL strongly predicts accelerated EDSS progression and cognitive decline.
- Chronicity / Half-Life: Once established, paramagnetic rims persist for years with an estimated half-life of 7-10 years.
- 100% Specificity: PRLs are 100% specific for MS compared to non-MS demyelinating conditions (MOGAD/NMOSD).
- 2024 Criteria Role: Presence of >=1 PRL serves as supportive evidence combining with CSF or DIT in single-topography MS.

Paramagnetic Rim Sign



PMR by MRI field strength. A, 7T T2* shows a PMR sign (arrow) that is not well seen on (B) 3T SWI or 1.5 T (C)

Cortical Lesions



Calabrese, M., Magliozzi, R., Tamanti, A. et al. Cortical lesions in multiple sclerosis: 25 years of progress, remaining challenges and future directions. Nat Rev Neurol (2026)

Cortical & Intracortical Pathology : 7 T High-Resolution Double Inversion Recovery and Phase sensitive Inversion Recovery

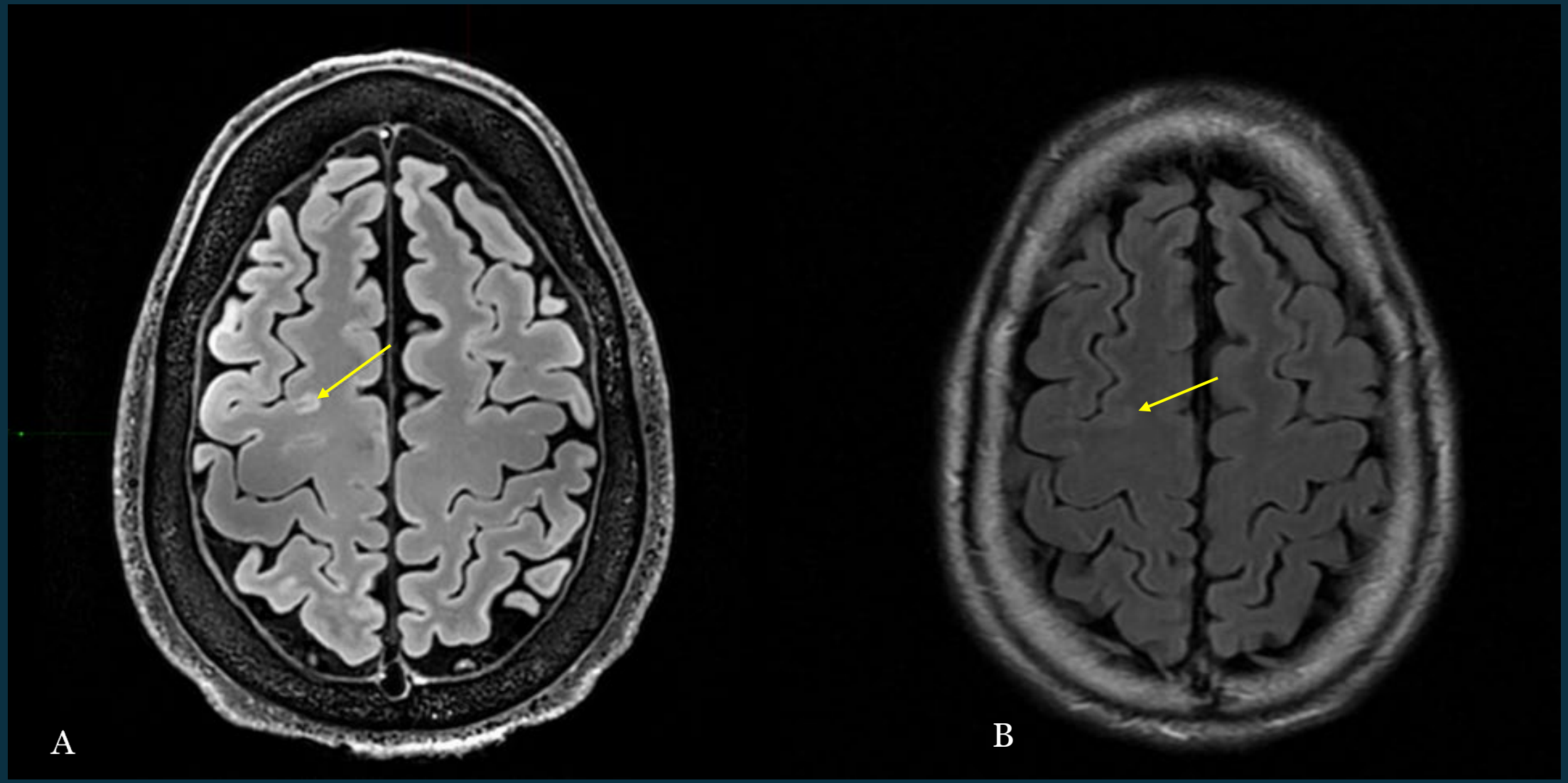
Cortical Demyelination Pathology

- Demyelination Types: Intracortical (Type I), leukocortical (Type II), subpial (Type III/IV).
- Pathological Burden: Cortical lesions constitute up to 40% of total cerebral lesion volume in MS.
- 3T Obscuration: High intrinsic cortical T2 signal and CSF partial volume effects hide >80% of cortical lesions at 3T.
- Clinical Significance: Cortical lesion burden correlates strongly with cognitive impairment and physical disability worsening.

7T Sequence Superiority (DIR / PSIR)

- 3D Double Inversion Recovery (DIR): Suppresses both CSF and white matter signals, making hyperintense intracortical plaques stand out.
- Phase-Sensitive Inversion Recovery (PSIR): Uses phase inversion to null white matter and maximize grey-white contrast.
- High-Field Yield: 7T DIR detects more cortical lesions than 3T DIR.
- Diagnostic Specificity: Cortical lesions are highly specific for MS and virtually absent in migraine and vascular disease.

Cortical Lesions



Cortical lesions by field strength. Cortical FLAIR hyperintense lesion on 7T (A) which is not well conspicuous on 3T (B)

SCENARIO INTEGRATION

CVS and PRL Biomarkers Substitute for Invasive CSF or Repeat Follow-Up Scans

Scenario 1 (Typical CIS + DIS)	Diagnosed by: DIT OR CSF positivity (OCBs/kFLCs) OR >=6 CVS lesions OR lesions in 4-5 topographies
Scenario 2 (Single Topography)	Diagnosed by: [DIT OR CSF positivity] COMBINED WITH [>=6 CVS lesions OR >=1 PRL]
Scenario 3 (RIS / Asymptomatic)	Diagnosed by: DIS COMBINED WITH [DIT OR CSF positivity OR >=6 CVS lesions]
Scenario 4 (Age >50 / Vascular)	Strongly requires: Spinal cord lesion OR CSF positivity OR >=6 CVS lesions to rule out mimickers
Scenario 5 (Pediatric / ADEM)	Requires: 2nd clinical attack OR new T2 lesions >90 days post-ADEM; ~50% CVS strongly indicates POMS

Technical Pitfalls & Artifact Mitigation

• Dielectric B1 Inhomogeneity: High RF frequency at 7T causes central shading; corrected using B1 transmit modes.

• B0 Susceptibility Distortions: Air-tissue interfaces create local magnetic gradients; minimized by high BW and thin slices.

• Motion Sensitivity: High spatial resolution increases scan time (5-8 min); head fixation and rapid 3D EPI acceleration are required.

Future Directions & Clinical Translation

- Widespread Clinical 7T Adoption: FDA-cleared 7T scanners expanding in clinical centers.
- Automated AI CVS/PRL Detection: Deep learning algorithms to automate CVS and PMR to expedite daily workflow.
- Future Criteria Inclusion: 7T ultra-high-field MRI recommended as primary imaging for complex or non-diagnostic MS presentations. Including cortical lesions in the criteria with future update, considering the poor prognostication and early clinical decline in MS patients

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THANK YOU

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