Glymphatics in SIH

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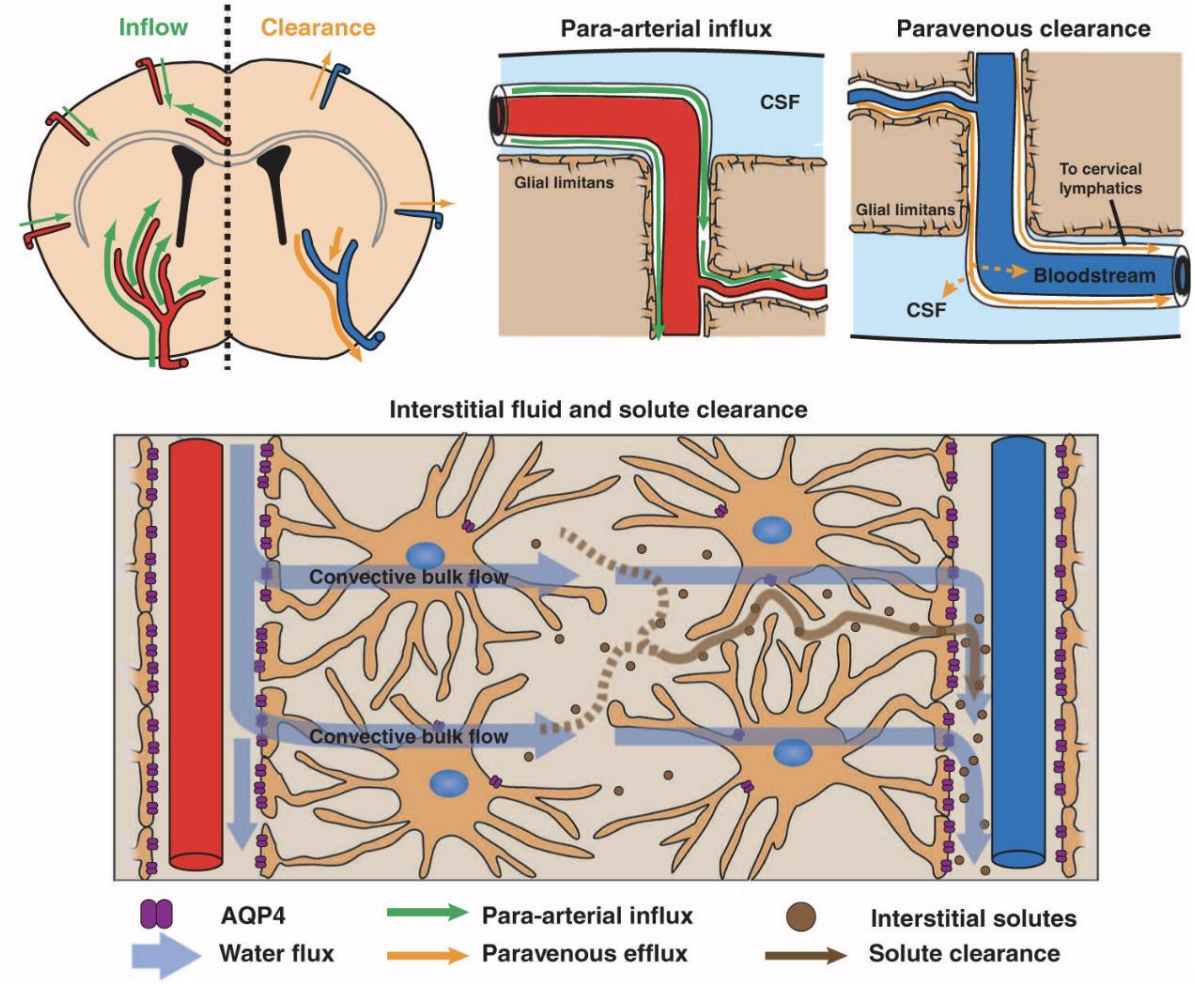
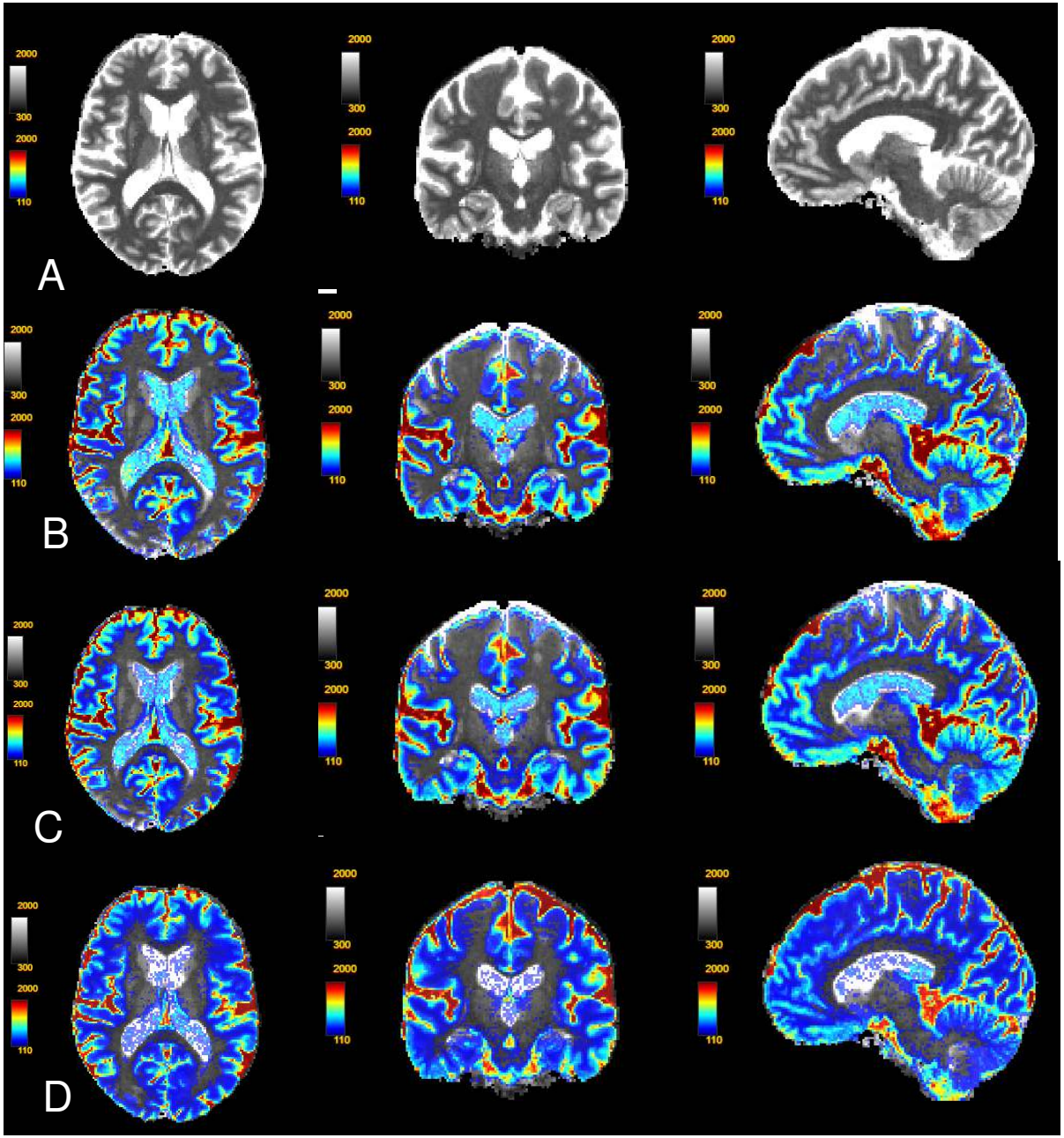
Glymphatic system ≈ CSF flow through the brain



Iliff J et al. A Paravascular Pathway Facilitates CSF Flow Through the Brain Parenchyma and the Clearance of Interstitial Solutes, Including Amyloid β. Sci Transl Med. 2012
Nedergaard M. Garbage Truck of the Brain. Science. 2013

Difference maps of T1 relaxation times



vor

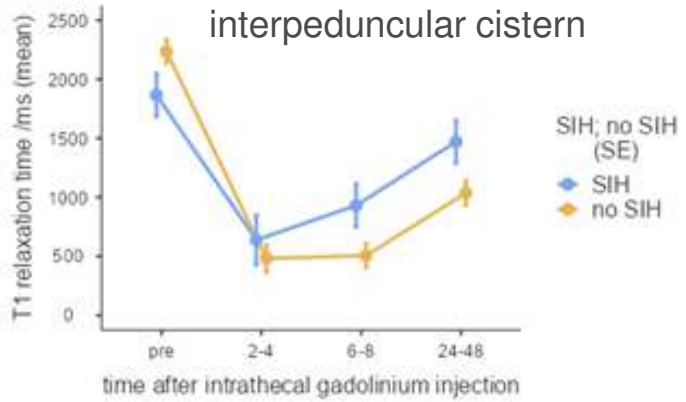
0,5 ml Gadobutrol i.th

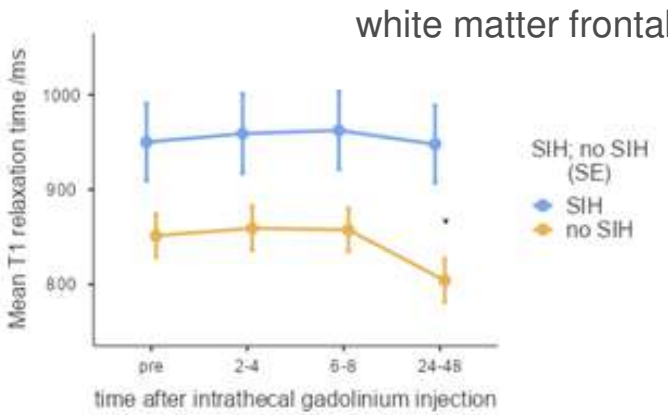
2-4 h

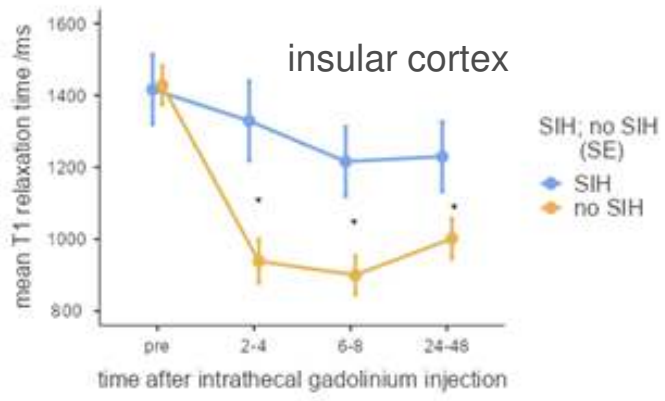
6-8 h

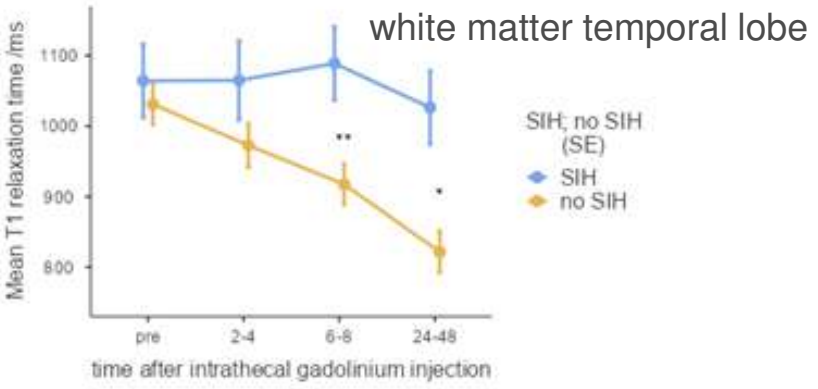
24-48 h

CSF inflow: perilsylvian subarachnoid space → cortex → white matter





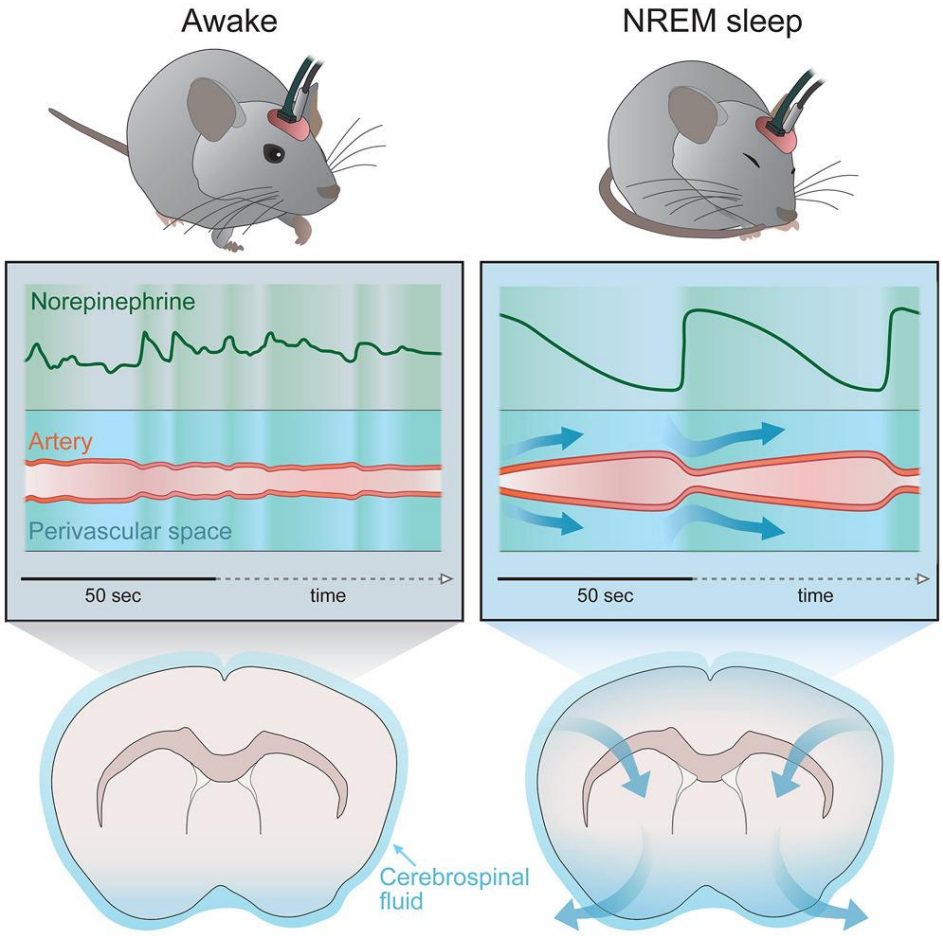




…driven by arterial pulsations, …, *and* CSF pressure
…intracranial CSF pressure is higher when lying down

Urbach H et al. Different glymphatic kinetics in SIH. AJNR 2024

Glymphatic transport in NREM sleep



“Vasomotion acts as a pump driving CSF into the brain”

Hauglund NL, …, Nedergaard M. Norepinephrine-mediated slow vasomotion drives glymphatic clearance during sleep. Cell 2025 Jan 8:S0092-8674(24)01343-6

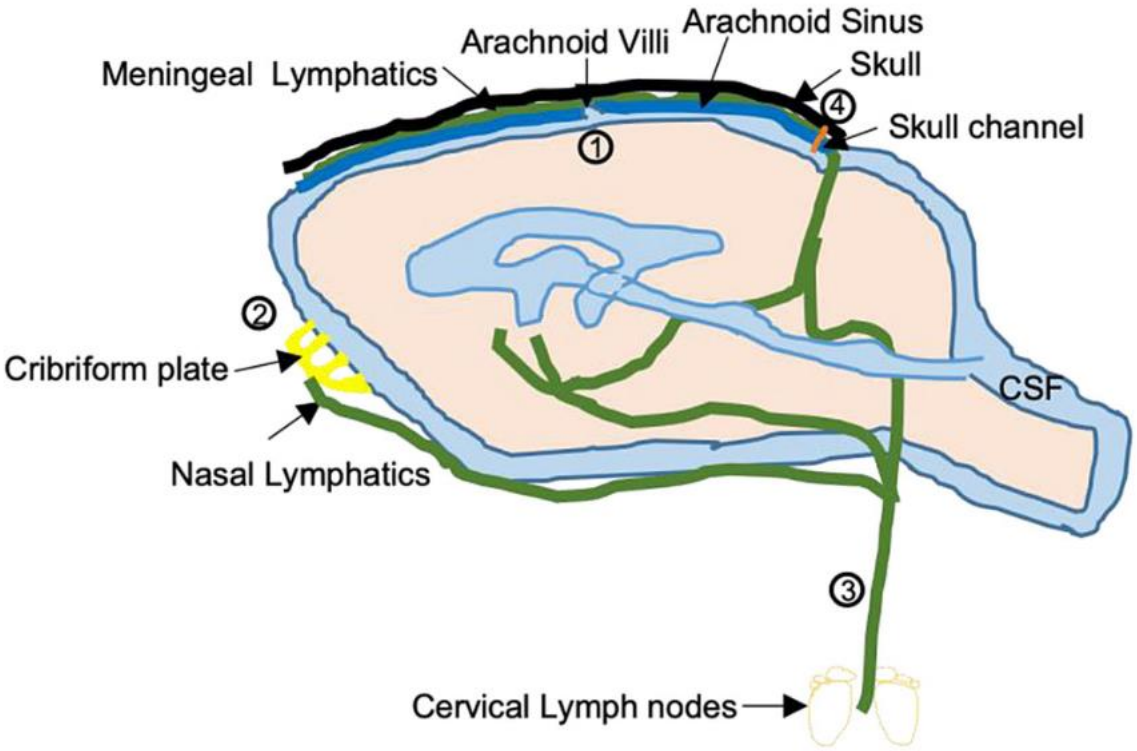
CSF (in)flow is influenced by

- cardiac pulsations
- respiration
  - „resisted inspiration for detection of CVF“ Mark IT AJNR 2022
- posture / gravity
  - intracranial CSF pressure is higher when lying down in COPD, sleep apnea, IIH …
- Sleep
  - „Norepinephrine-mediated slow vasomotion during sleep in rats”

    Hauglund NL Cell 2025
- neuronal activity
- CSF pressure
  - Urbach H AJNR 2024, Wolf K Neurology 2023
- ….?

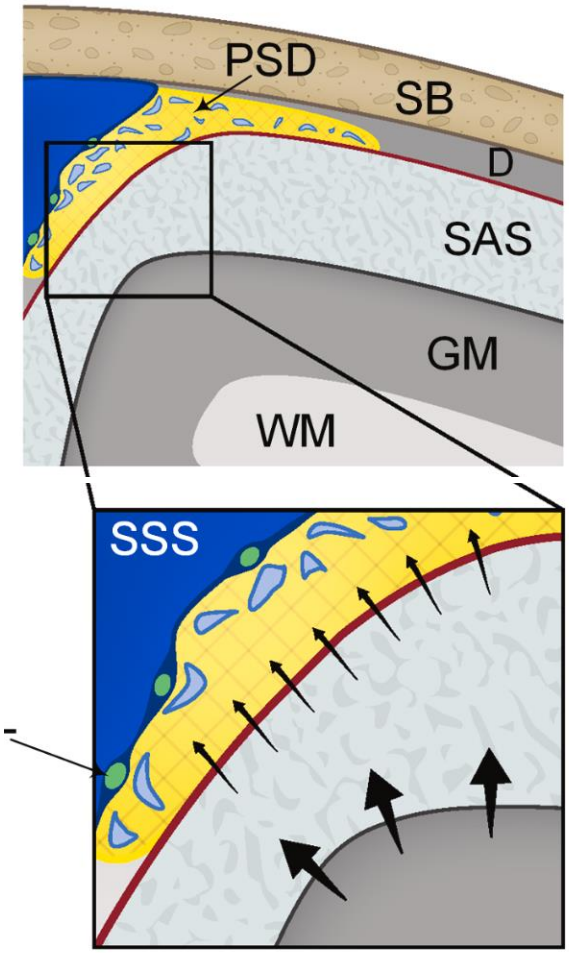
CSF outflow: brain → lymphatics → cervical lymph nodes

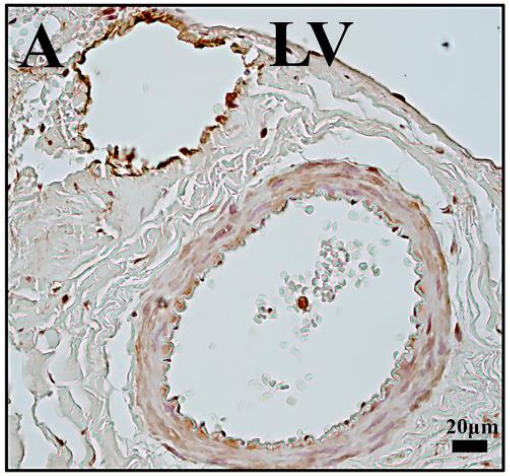
1 parasagittal dura
2 nasal

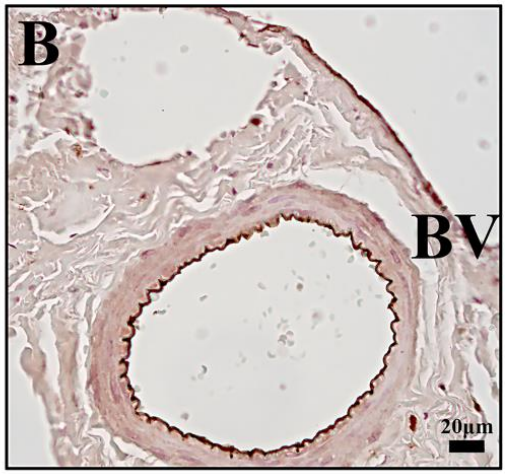


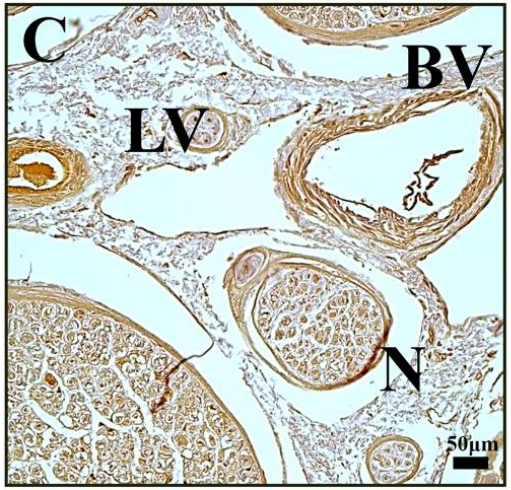
Licastro E et al. Glymphatic and lymphatic communication with systemic responses during physiological and pathological conditions in the central nervous system. Communications Biology 2024;7:229

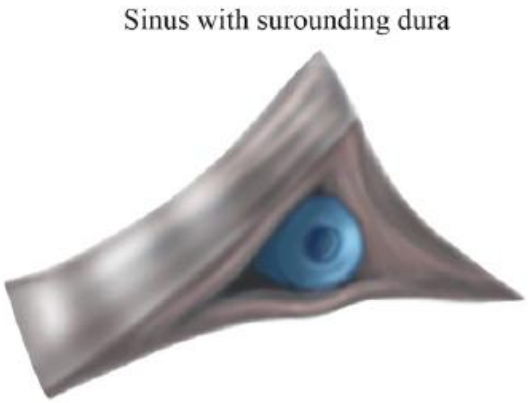
Glymphatic transport to dural lymphatics





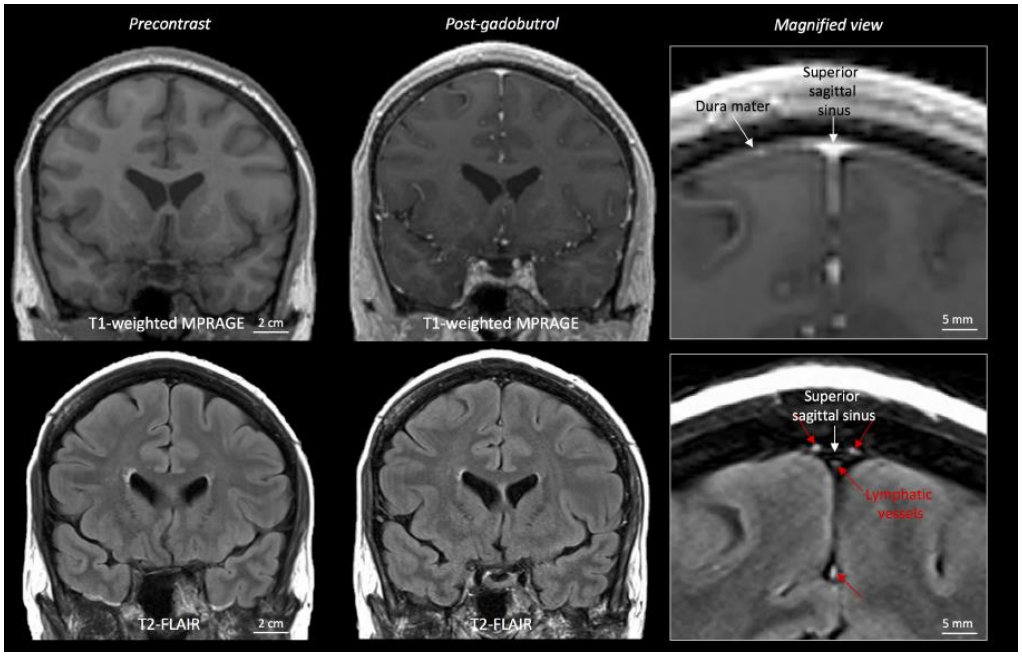




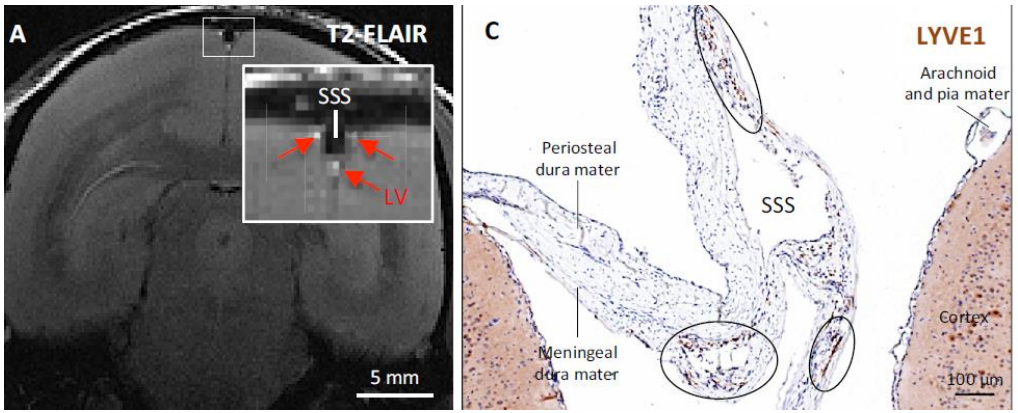


Eide PK, Ringstad G. Brain Research 2021:1772:147669
Çavdar S et al. J Chem Neuroanatomy 2023;134:102357

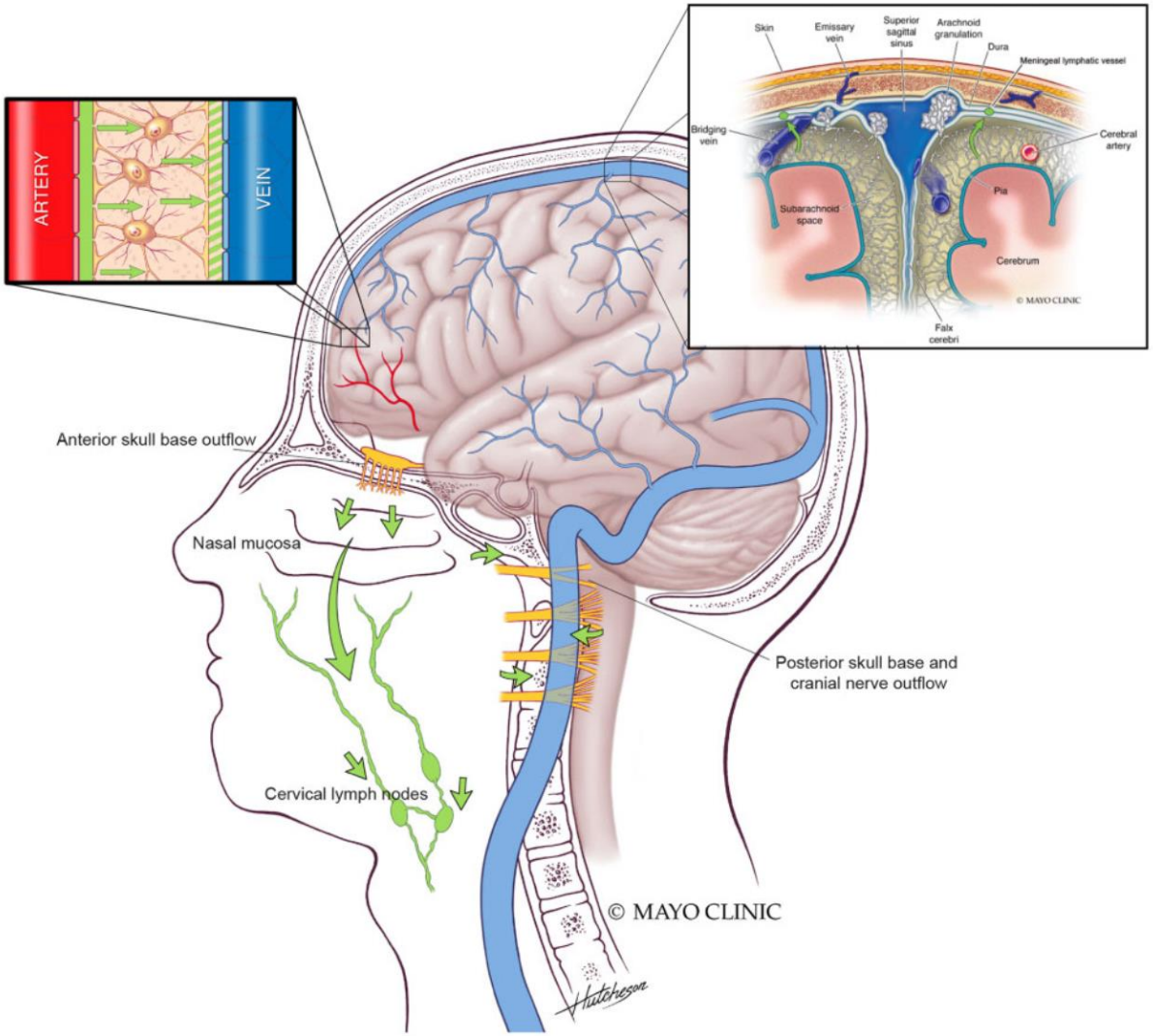
Dural lymphatics



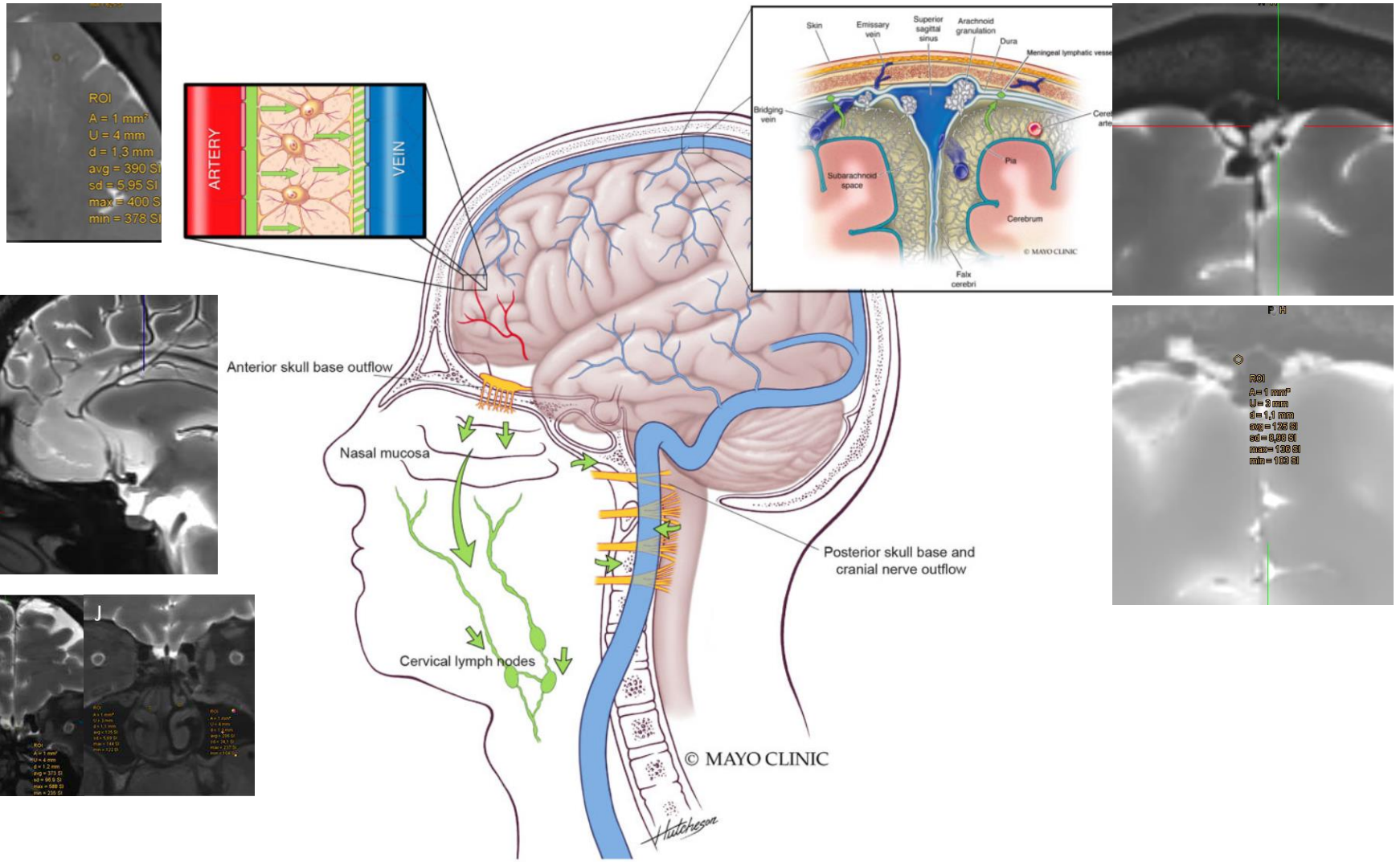
FLAIR nach Gadolinium



Absinta M et al. Human and nonhuman primate meninges harbor lymphatic vessels that can be visualized noninvasively by MRI. eLife 2017;6:e29738.



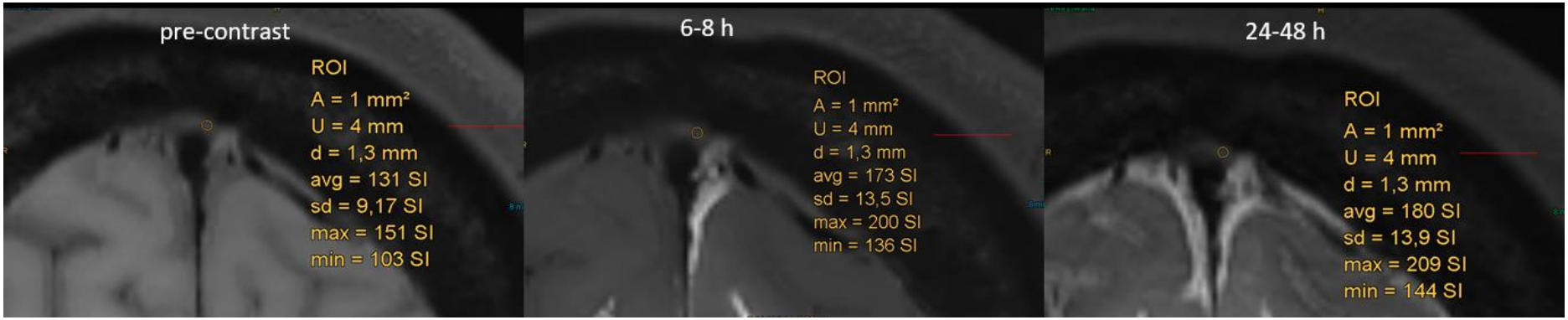
Carlstrom LP et al. Brain 2022:145;843–857



Carlstrom LP et al. Brain 2022:145;843–857

SI parasagittal dura excluding arachnoid granulations

3D T1-w CS-BB-SPACE (0.5x0.5x0.6 mm)



131 173 180

Signal intensities normalized to vitreous body	pre	2-4h	6-8h	24-48h	72-96h
Parasagittal dura	153±27.5	154±30.25	171±36.8	167±32.3	183±20.4

Urbach H et al. Different glymphatic-lymphatic coupling in the nasal mucosa and parasagittal dura. Invest Radiol in press

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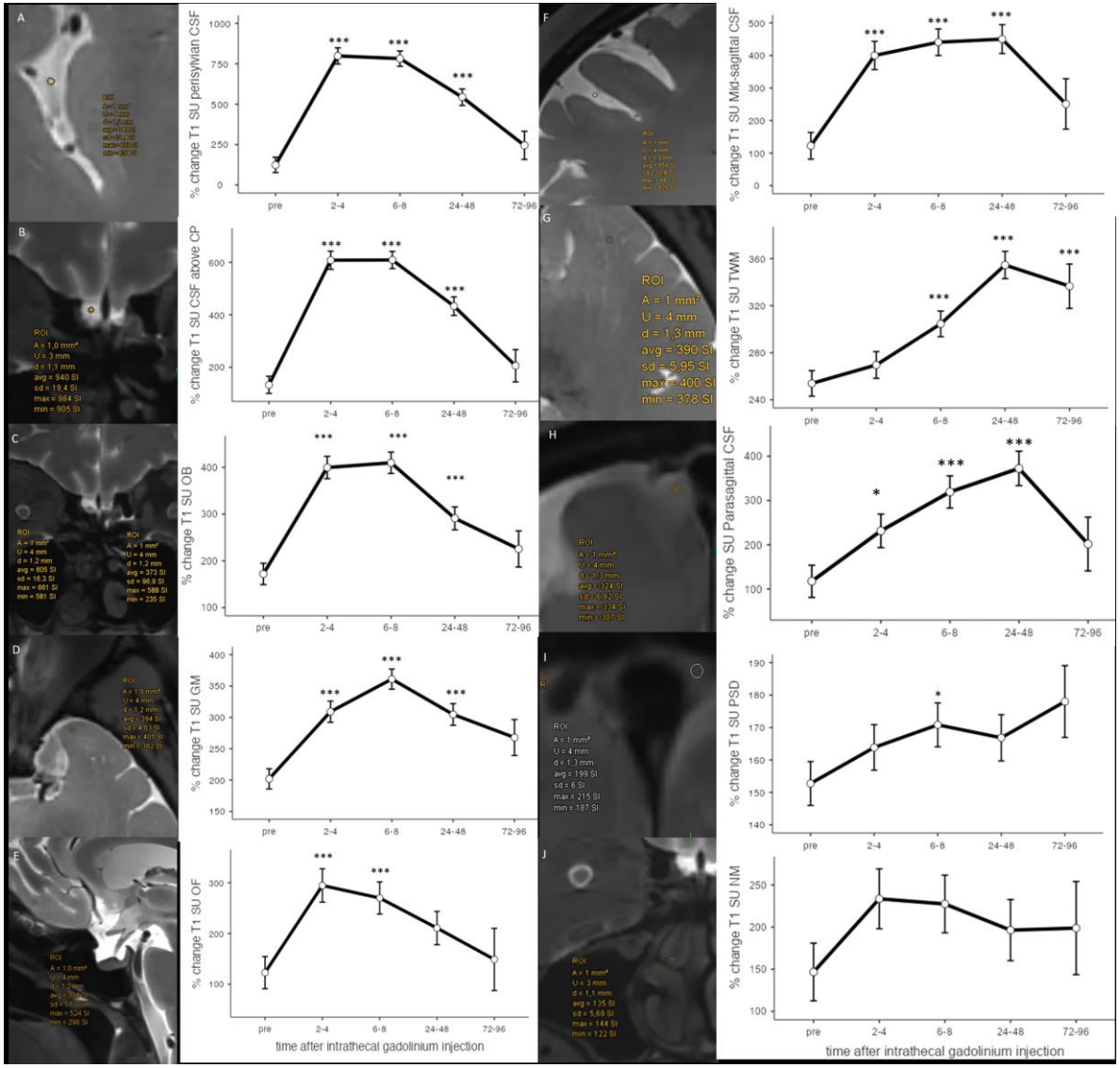
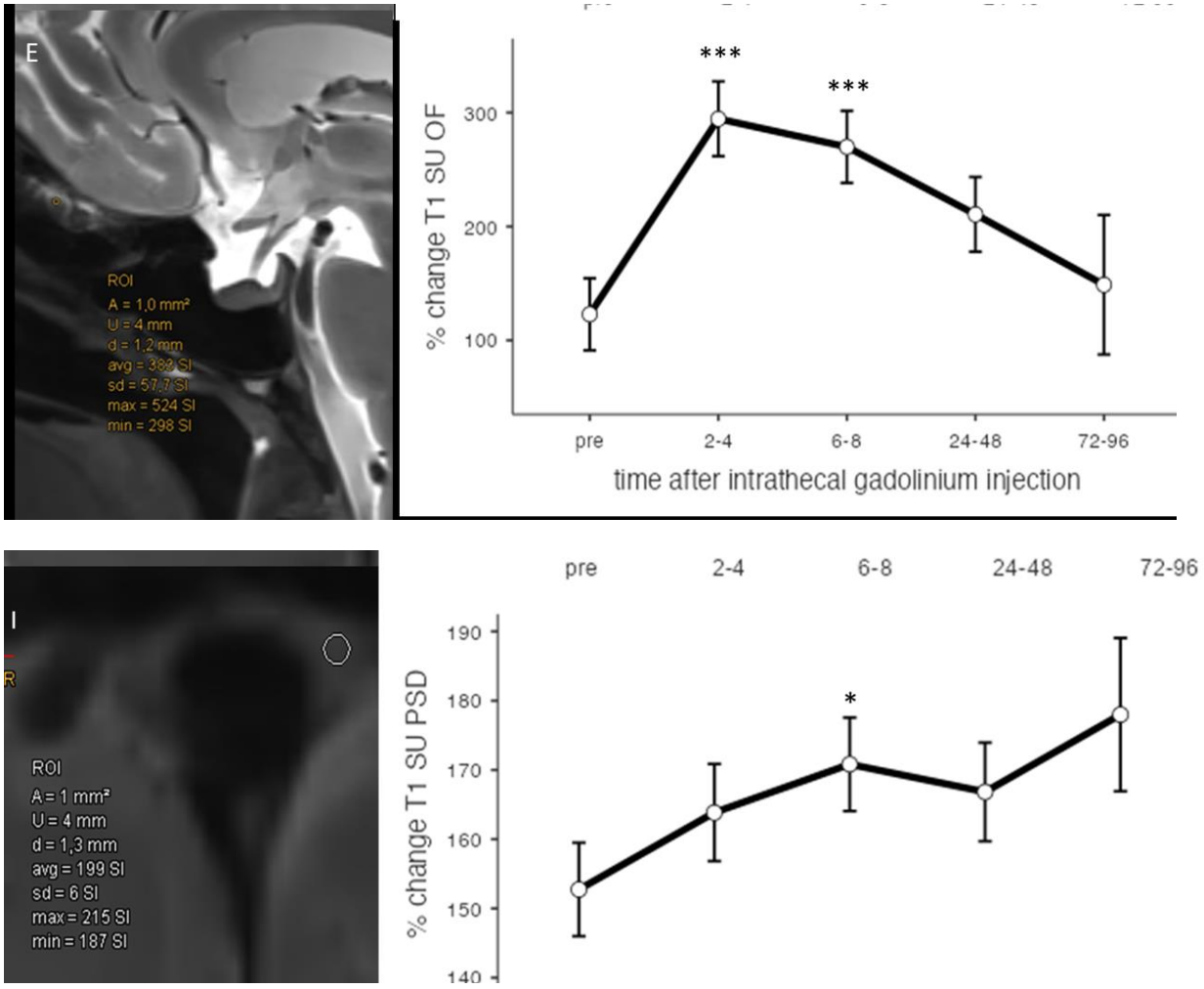


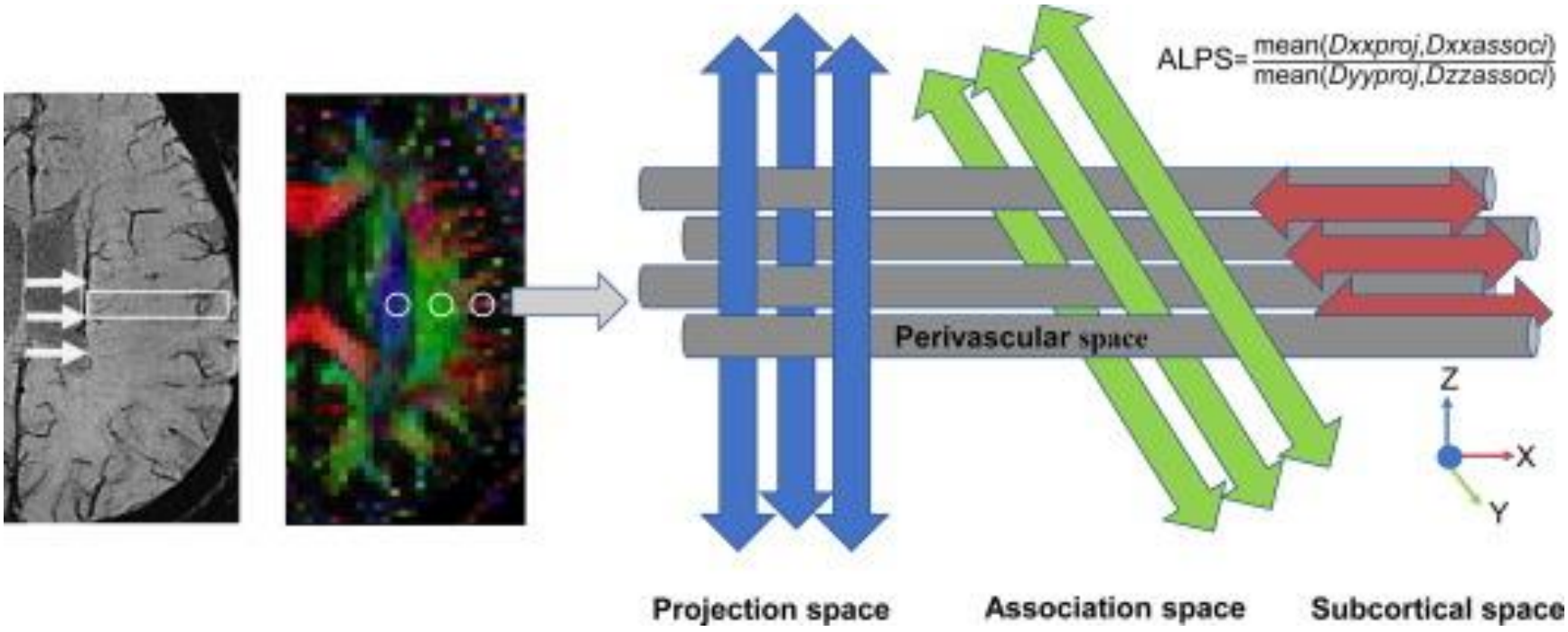
Urbach H et al. Different glymphatic-lymphatic coupling in the nasal mucosa and parasagittal dura. Invest Radiol in press



Urbach H et al. Different glymphatic-lymphatic coupling in the nasal mucosa and parasagittal dura. Invest Radiol in press

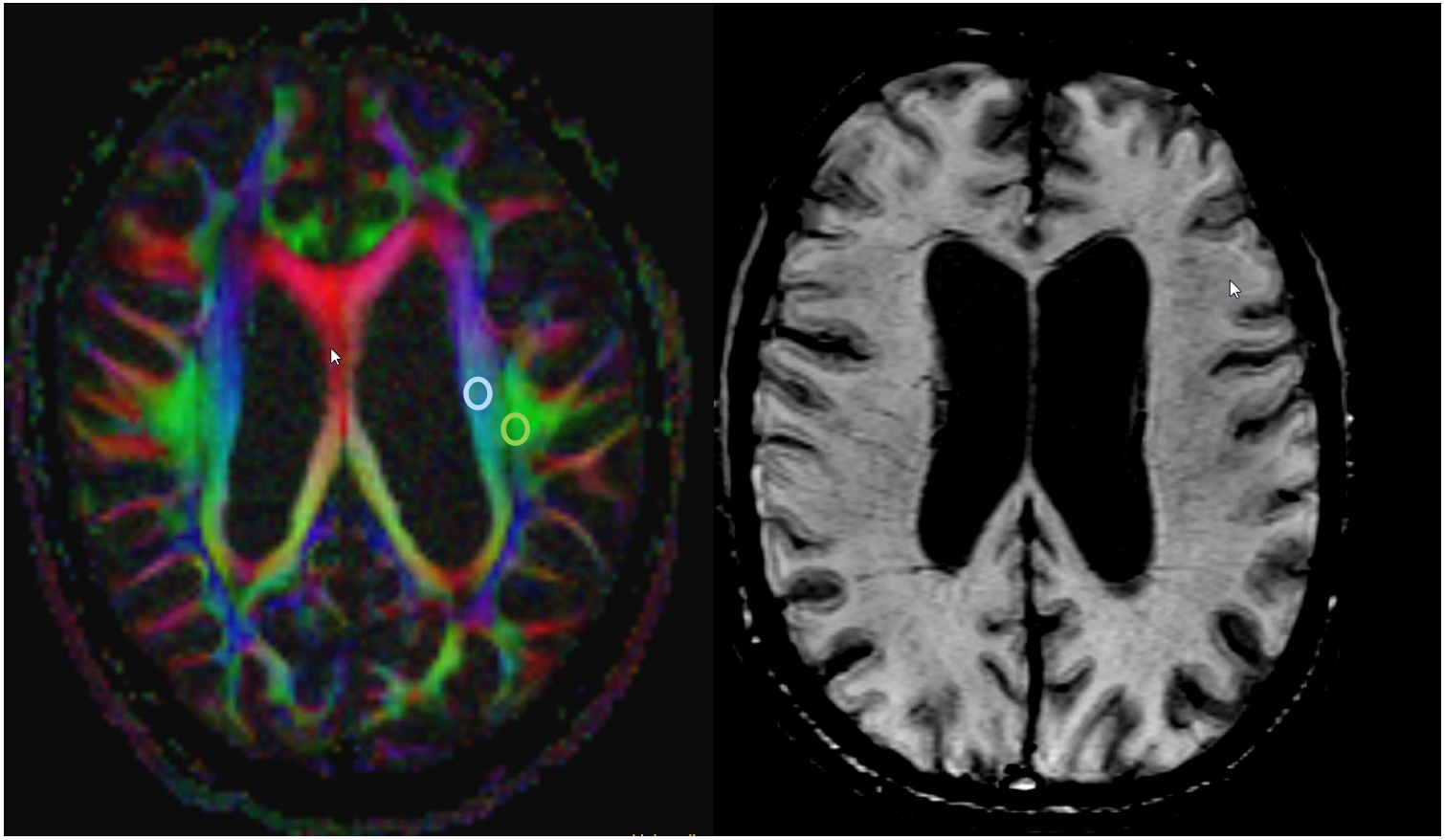
DTI-ALPS

along the perivascular space



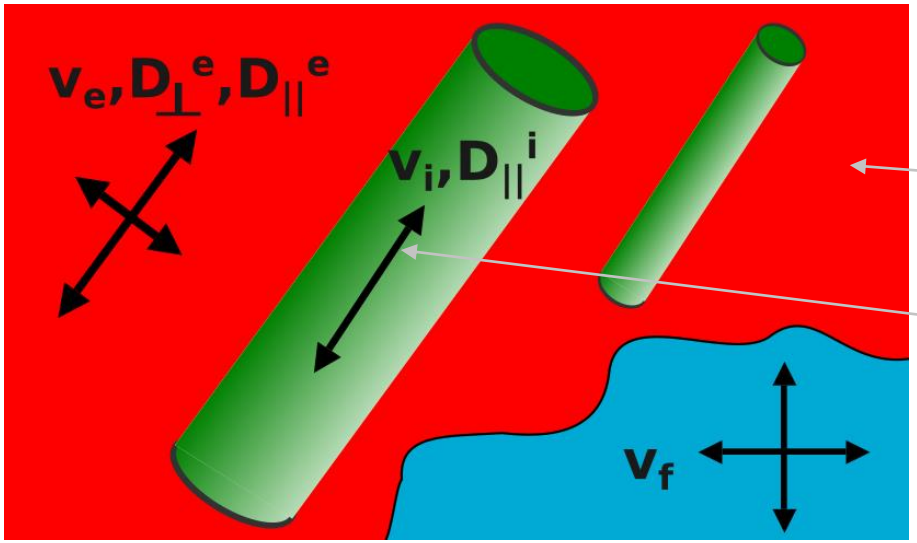
Taoka T et al. Evaluation of glymphatic system activity with the diffusion MR technique: diffusion tensor image analysis along the perivascular space (DTI-ALPS) in Alzheimer's disease cases. Jpn J Radiol 2017;35:172–178

DTI-ALPS



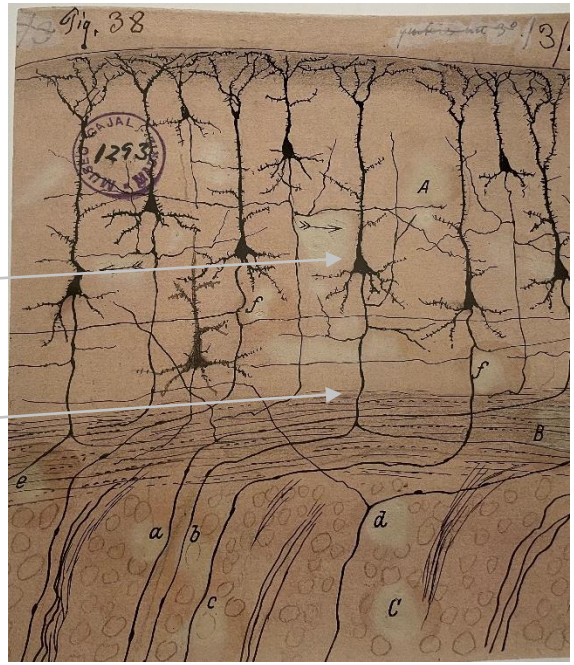
DMI

Ramon Y Cajal (1852-1934): The beautiful brain, p42: Pyramidenzellen des Kortex



10 µm

1 µm



$$M(q) = v_i e^{-D_\parallel^i t(q^T n)^2} + v_e e^{-D_\parallel^e t(q^T n)^2 - D_\perp t(|q|^2 - (q^T n)^2} + v_f e^{-3|q|^2}$$

„restricted“ compartment

Dax < 5 µm

„hindered“ compartment

5 µm < Dax+rad <10 µm

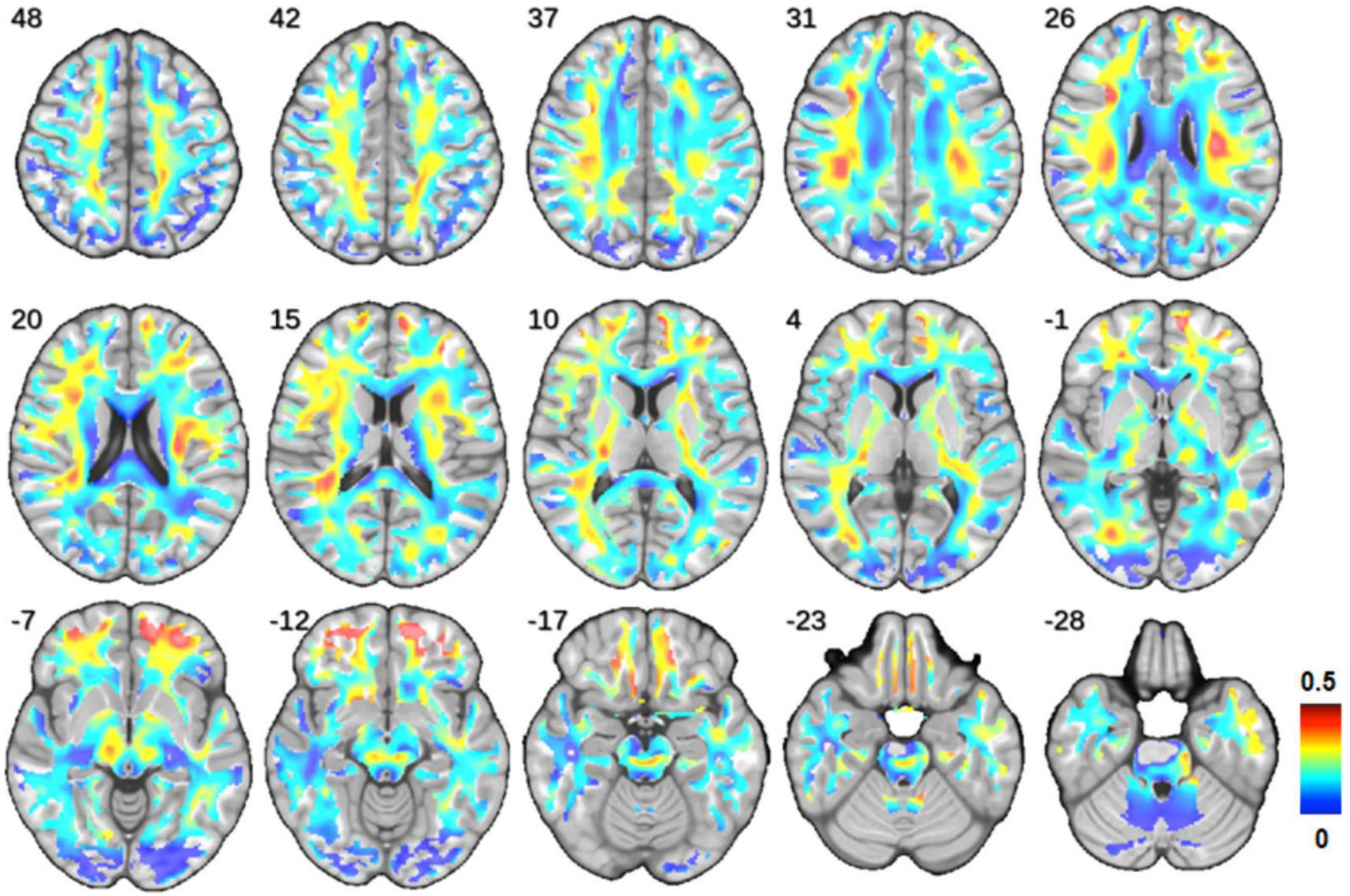
„free “ compartment

Dax+rad >10 µm

Reisert M et al. Disentangling micro from mesostructure by diffusion MRI: A Bayesian approach. NeuroImage 2017;147:964

COVID

V_{CSF} in white matter ⇧



Rau A et al. Widespread white matter oedema in subacute COVID-19 patients with neurological symptoms. Brain. 2022;145:3203-3213.

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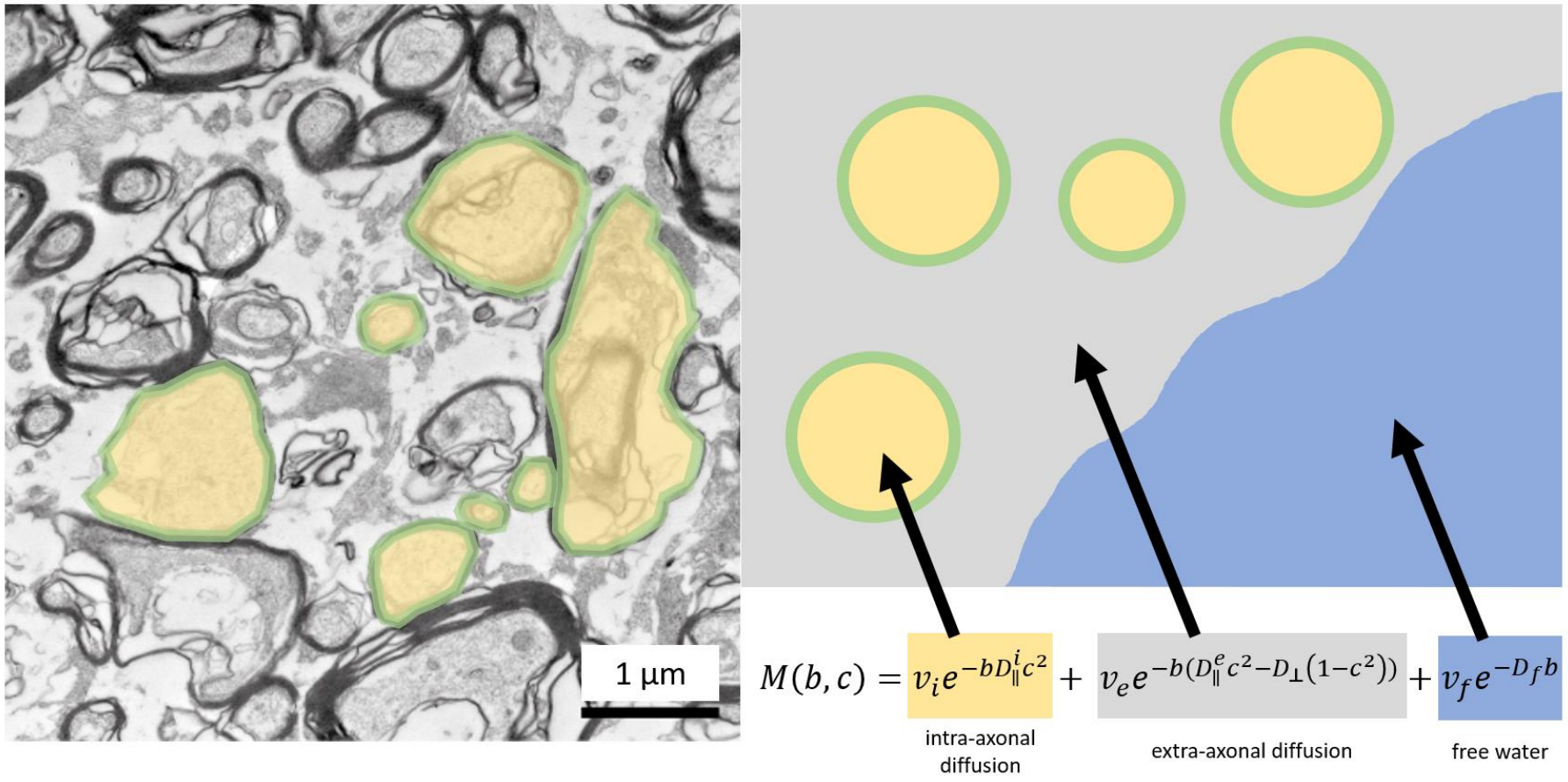
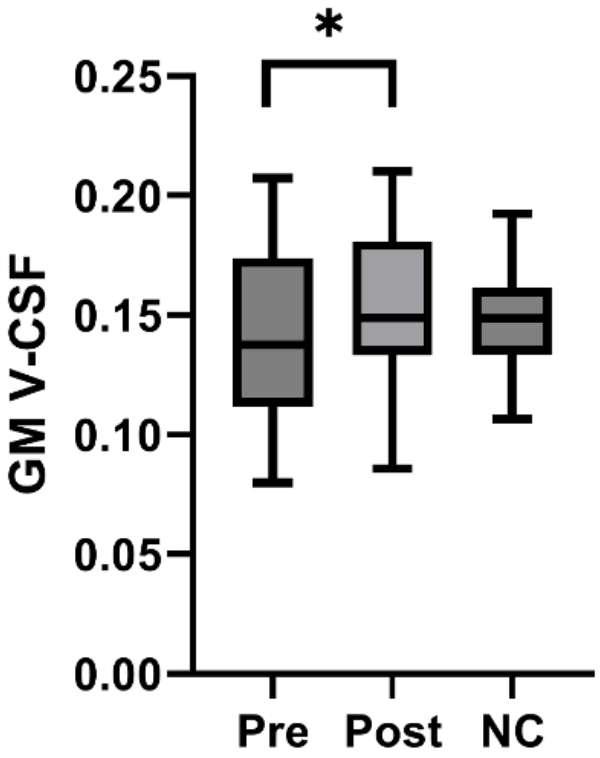
Diffusion Microstructure Imaging (DMI)

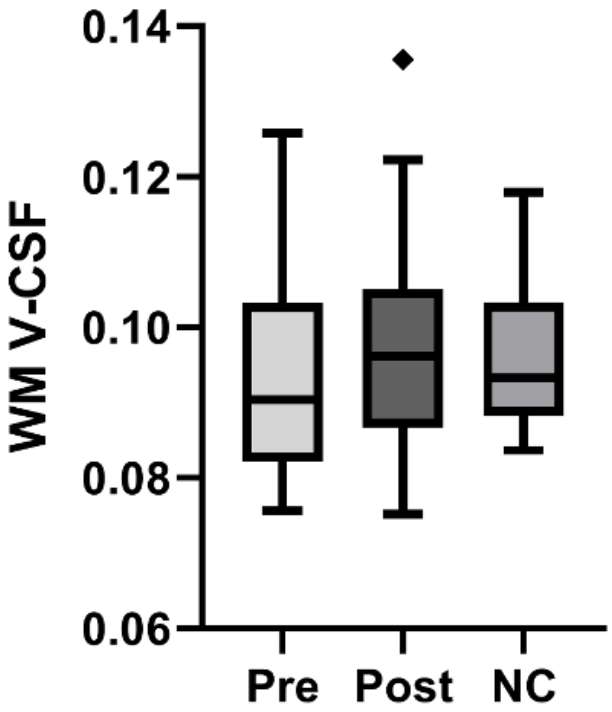


Demerath T et al. Gray-white matter blurring of the temporal pole associated with hippocampal sclerosis: A microstructural study involving 3T MRI and ultrastructural histopathology. Cereb Cortex. 2022;32:1882

SIH: Interstitial brain fluid



Gray matter



White matter

Zander C et al. Low interstitial fluid volume in patients with spontaneous intracranial hypotension: insights from diffusion microstructure imaging. In preparation

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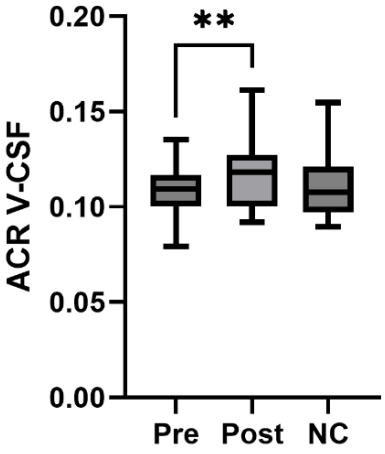
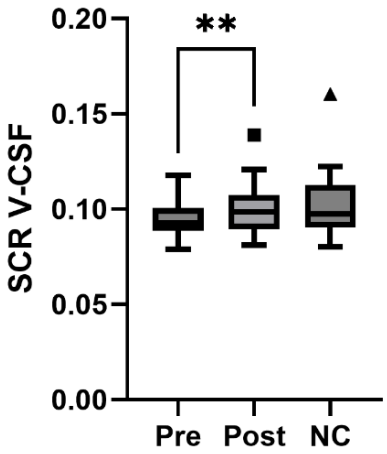
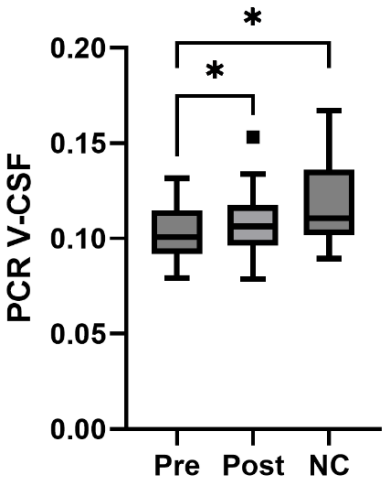
SIH: Interstitial brain fluid



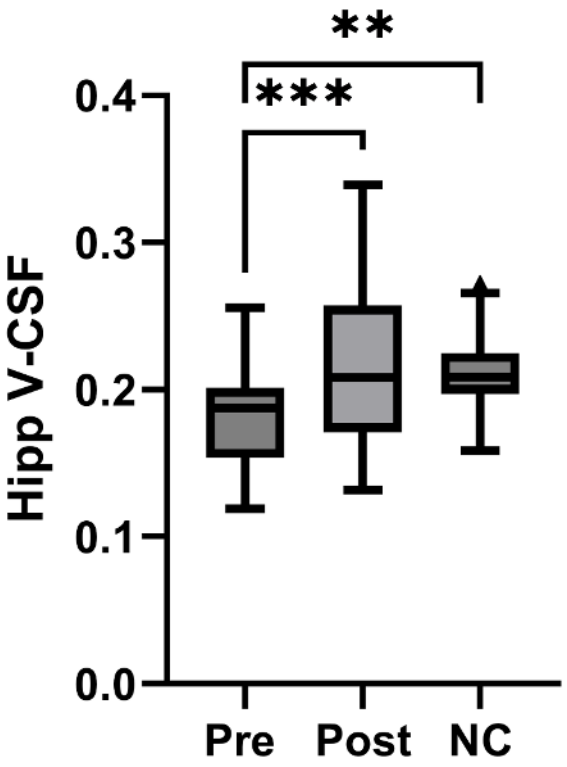




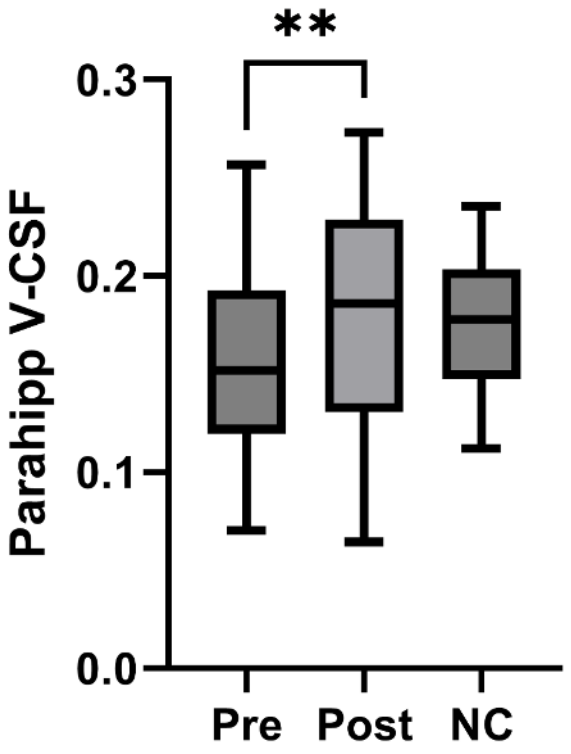
Corona radiata

Zander C et al. Low interstitial fluid volume in patients with spontaneous intracranial hypotension: insights from diffusion microstructure imaging. In preparation

SIH: Interstitial brain fluid



Hippocampus

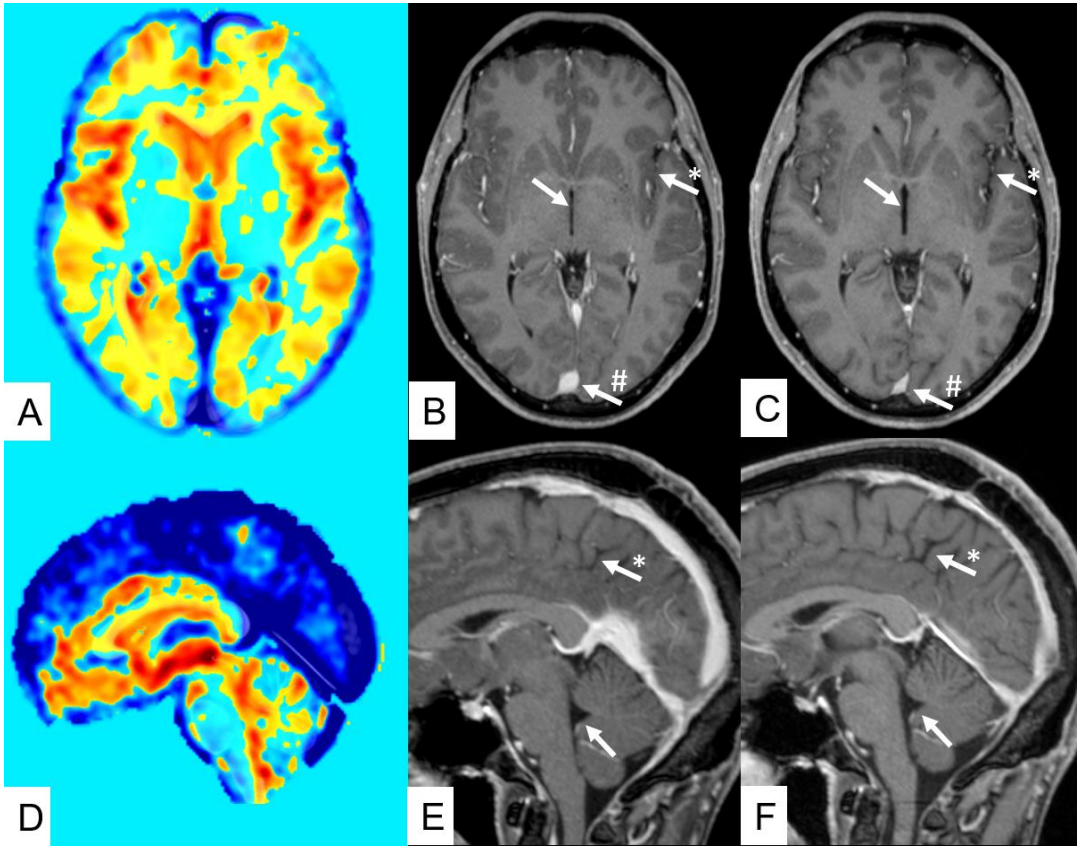


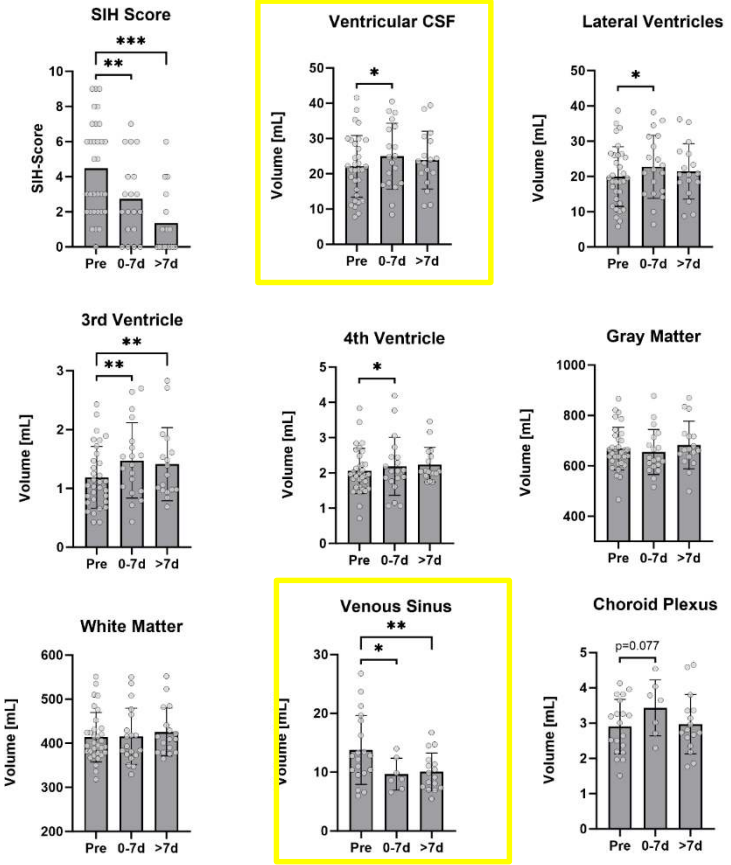
parahippocampal gyrus

Zander C et al. Low interstitial fluid volume in patients with spontaneous intracranial hypotension: insights from diffusion microstructure imaging. In preparation

Implications

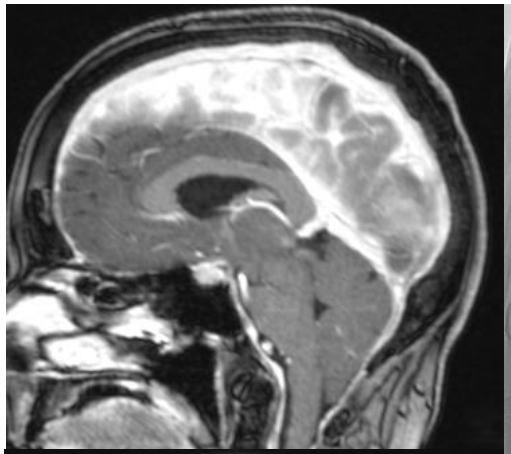
- to understand „brain fog“, „spinal MCI“, „spinal dementia“, „brain sagging dementia“ in SIH

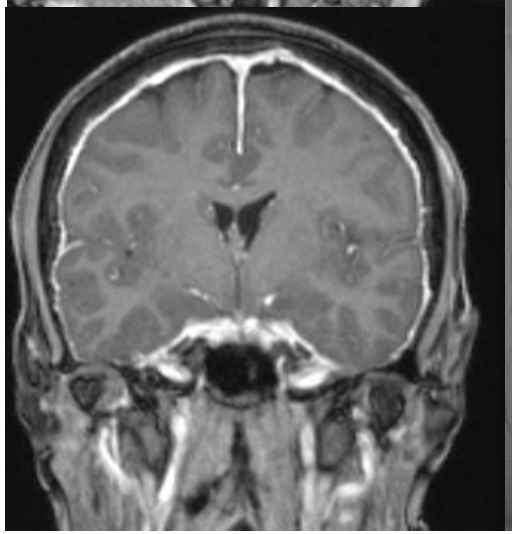


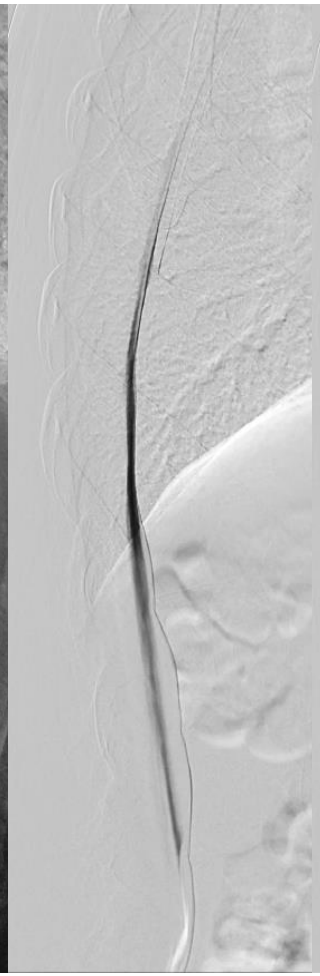


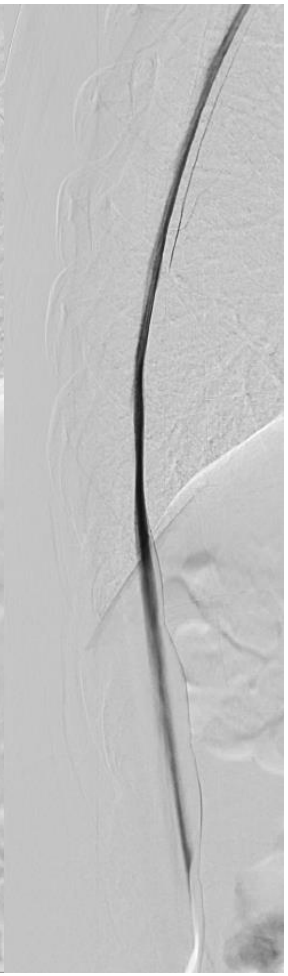
Zander C et al. Volumetric re-compensation after closure of a spinal CSF leak in patients with spontaneous intracranial hypotension: a multicompartmental longitudinal study. JNIS 2025

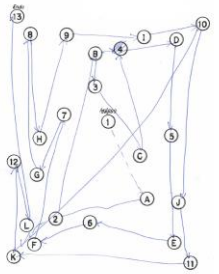
„spinal MCI“



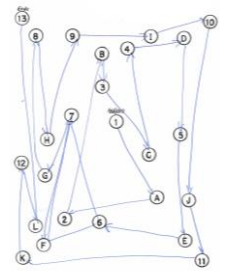




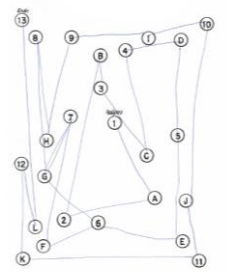




TMT B baseline:
112s. 3 mistakes. z-score 3.2



TMT B 48 hours after treatment:
89s, 3 mistakes, z-score 1.9



TMT B 3 months after surgery:
62s, 1 mistake, z-score 0.2

MoCA 26.5 ± 2 → 28.5 ± 1 , TMT B 2.1 ± 2 → 1.1 ± 1 s

Wolf K et al. Headache 2024, Wolf K et al. Headache 2025

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Implications

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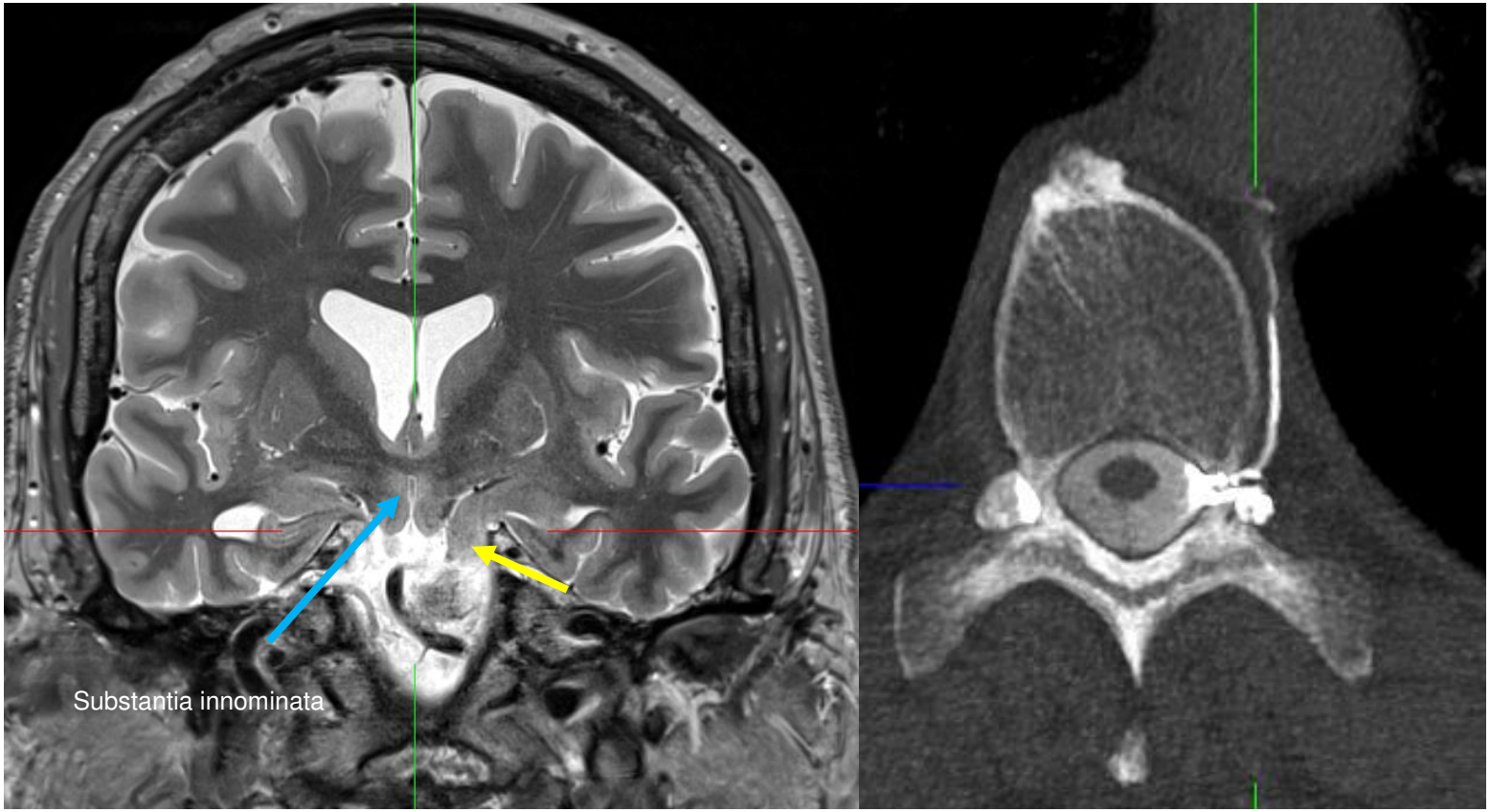

Urbach H et al. Neuroradiology 2025, Wolf K et al. Headache 2024, Wolf K et al. Headache 2025

Summary

We show with different MRI sequences

Gd cisternographie, T1-relaxometry, 3D-CS-BB-SPACE (0.5x0.5x0.6)

Diffusion microstructure imaging

that

CSF flow ≈ glymphatic transport ≈ is lower in patienst with SIH