Interaction between the CSF and the venous systems

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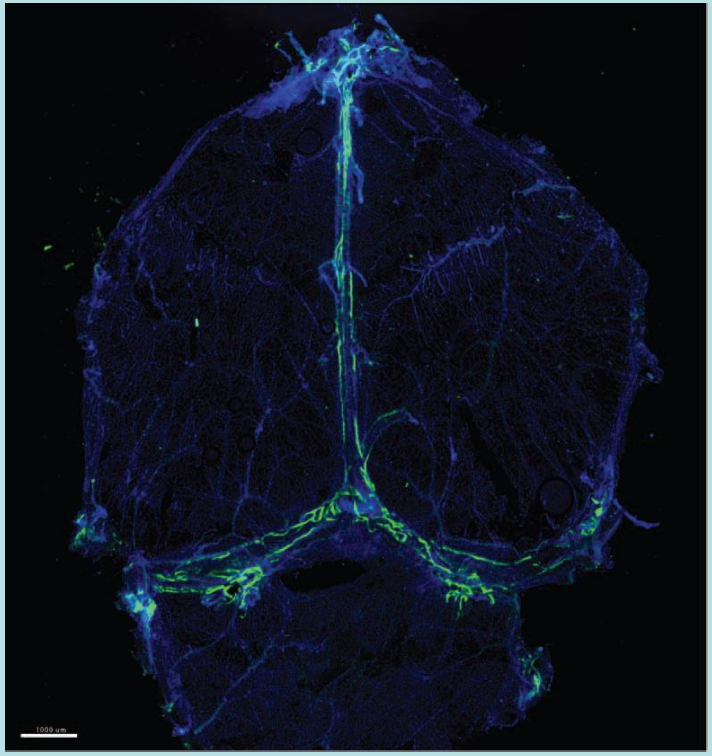
The background

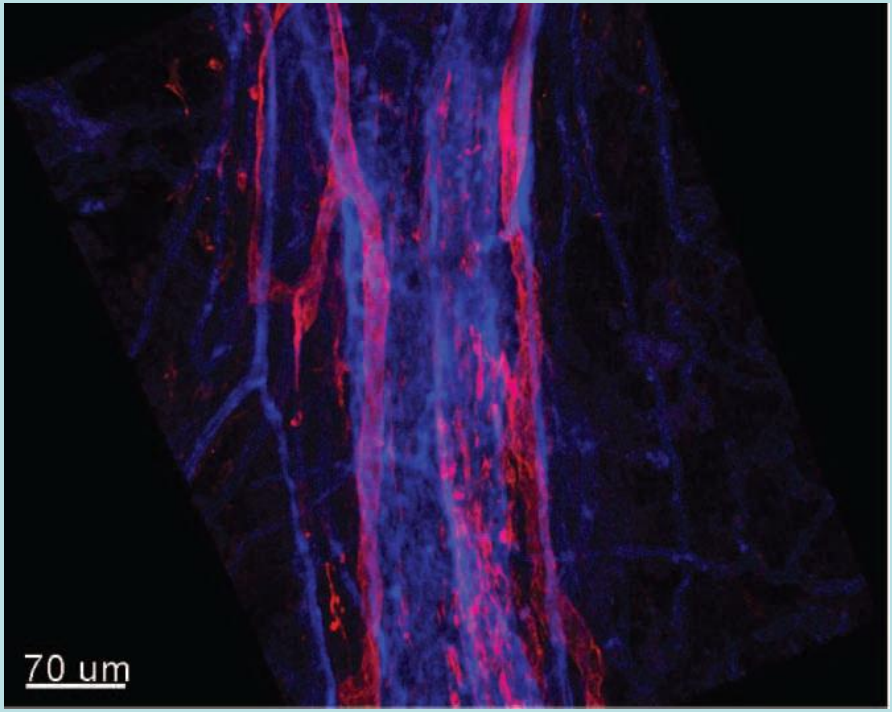
- Lymphatic system is a waste clearance system in the body.
- Although brain is the most biochemical active organ, there is no lymphatic system in the brain.

Because of the recent discovery of lymphatic vessels in the dura mater,

Modified: There is no lymphatic system in the brain parenchyma

Two groups discovered dura lymphatic vessels in mice



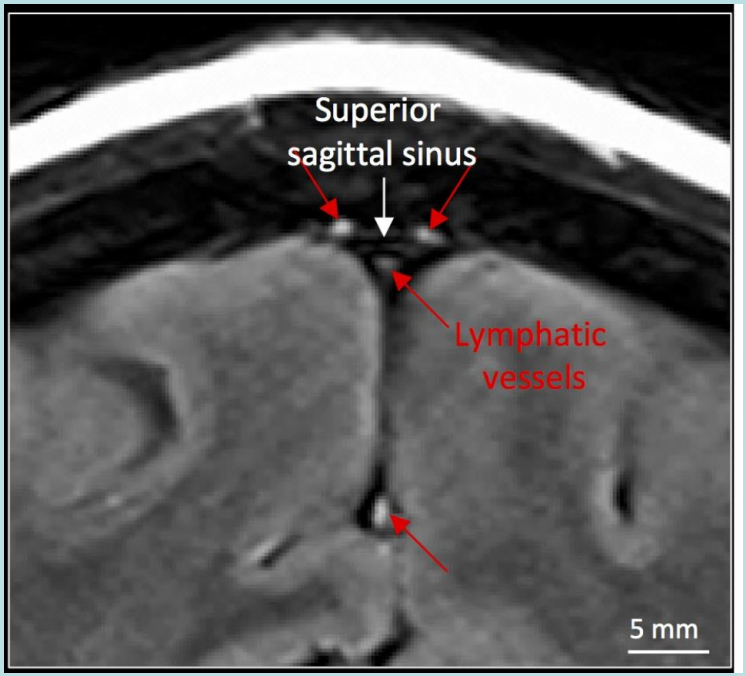


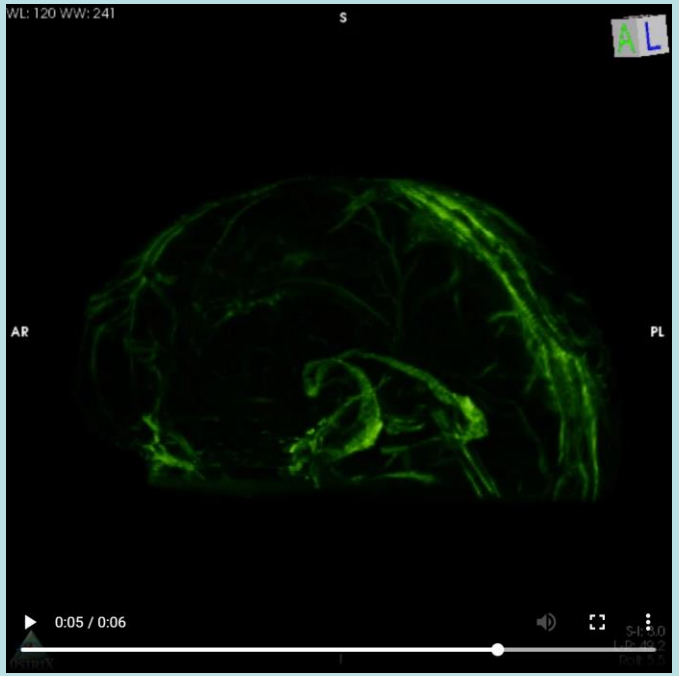
Left: Representative image of Lyve-1 (lymphatic endothelial cells marker) labelling on whole-mount meninges (**scale bar, 1,000 um**), along the superior sagittal sinus (SSS). Color: Lyve-1 DAPI

Right: Higher magnification of Lyve-1-expressing vessels (**scale bar, 70 mm**); Color: Lyve-1 CD31. **Conventional MRI cannot see them.**

Louveau A, et al. Nature. 2015;523:337-341; Aspelund A, et al. J Exp Med. 2015;212:991-999.

Does human dura have lymphatic vessels?





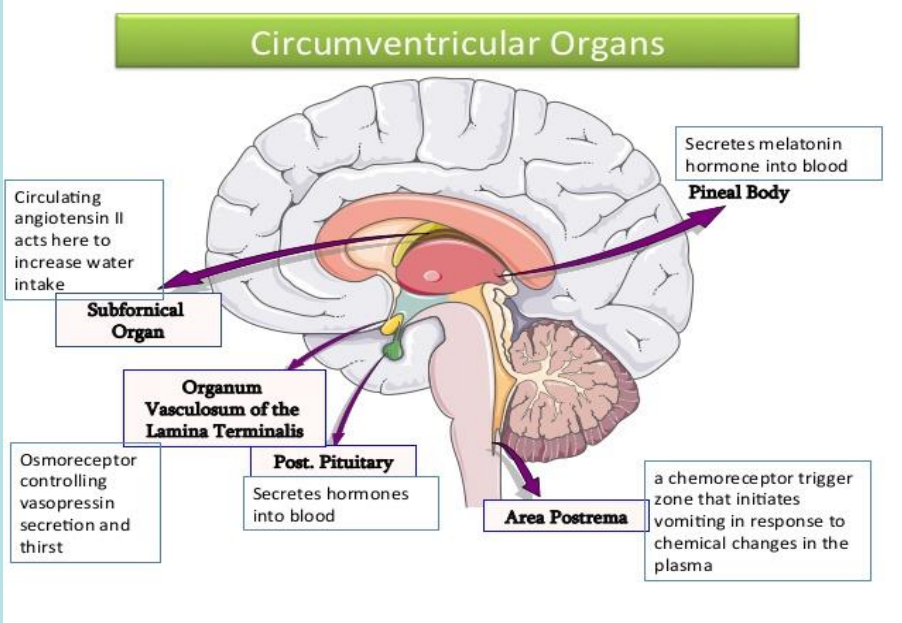
Milestone: MRI with IV-injected Gd-contrast agent.

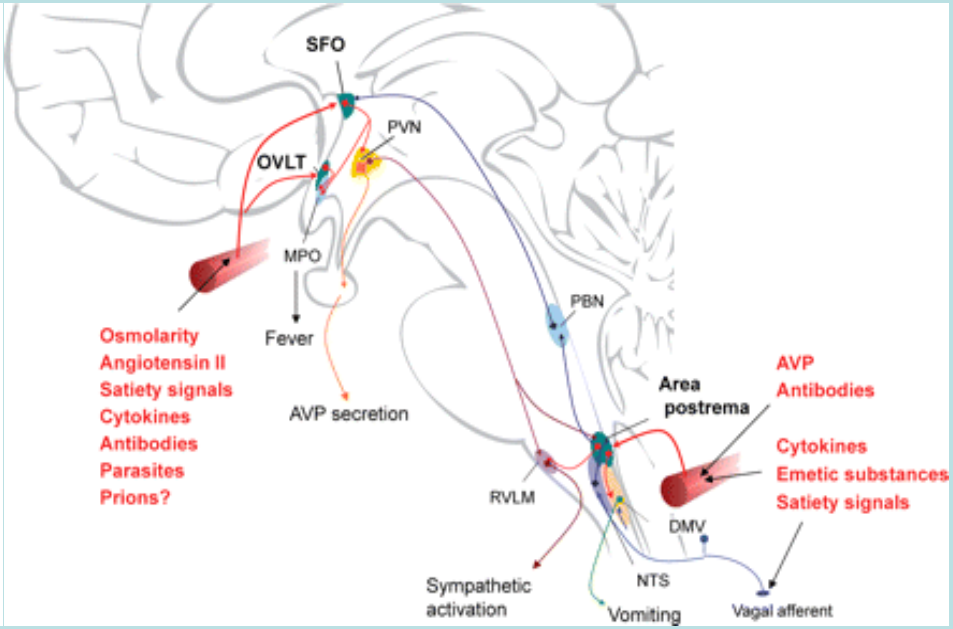
Their key result: black-blood MRI in the dura are dural lymphatic vessels;

But these are conventional MRI.

Absinta et al. eLife 2017;6:e29738. DOI: https://doi.org/10.7554/eLife.29738

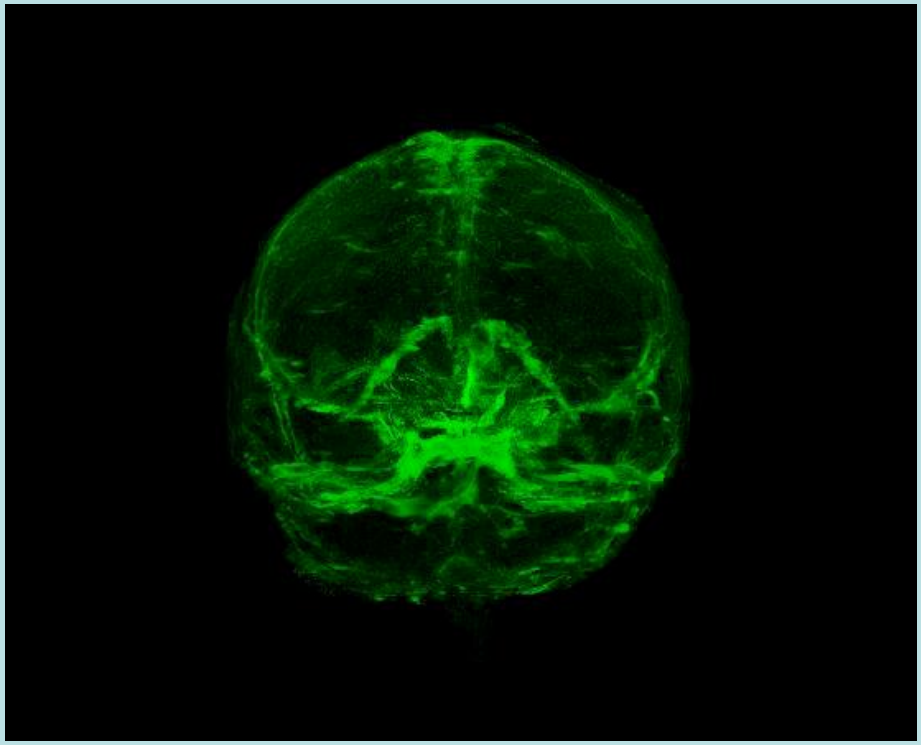
Organs in the brain with permeable capillaries: CVO, Choroid Plexuses (CP) and Dura,





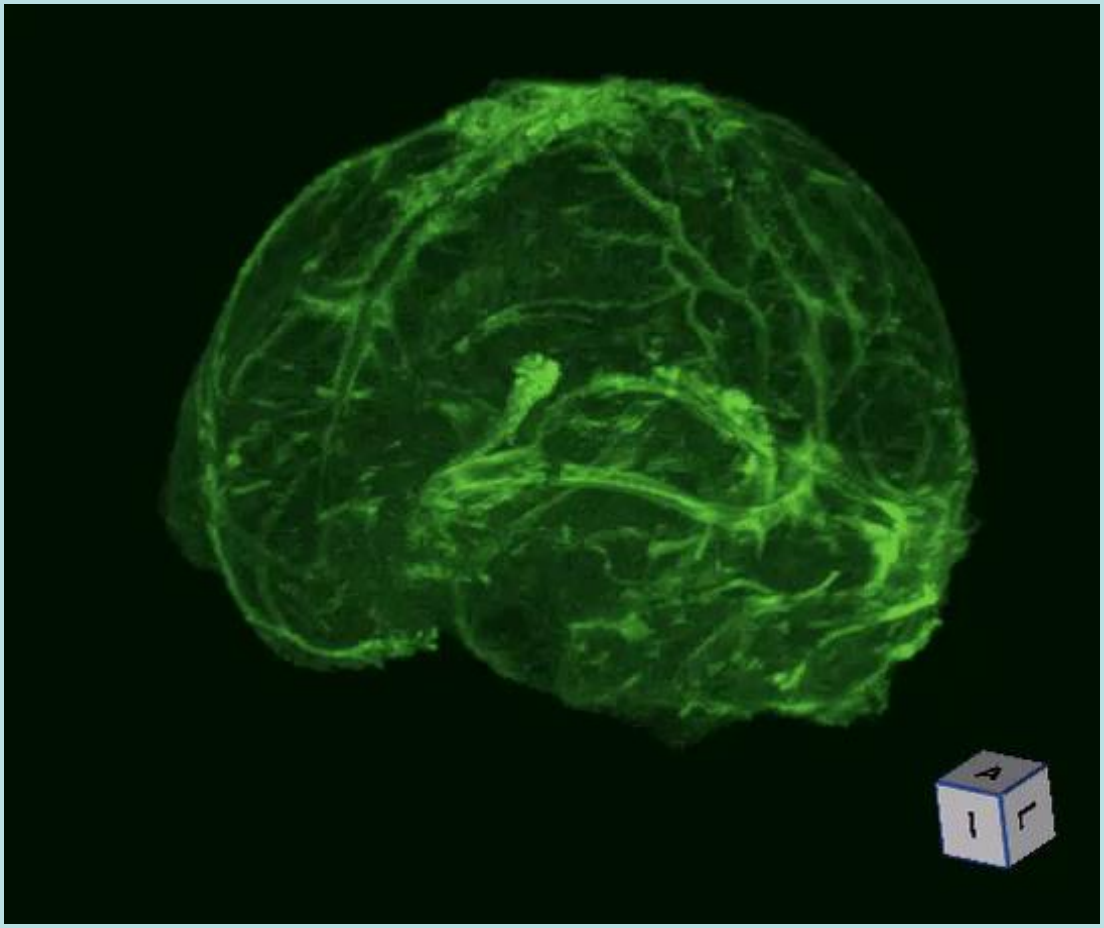
Circumventricular organs (CVO) serves homeostatic functions and body water balance. The sensory: the area postrema (AP), the subfornical organ (SFO) and the vascular organ of lamina terminalis (VOLT). The secretory organs: the subcommissural organ (SCO), the pituitary gland, the median eminence, and the pineal gland.

Our results of black-blood MRI with IV injected gadobutrol (The same method): Organs with permeable capillaries (CVO, Choroid Plexuses and Dura)



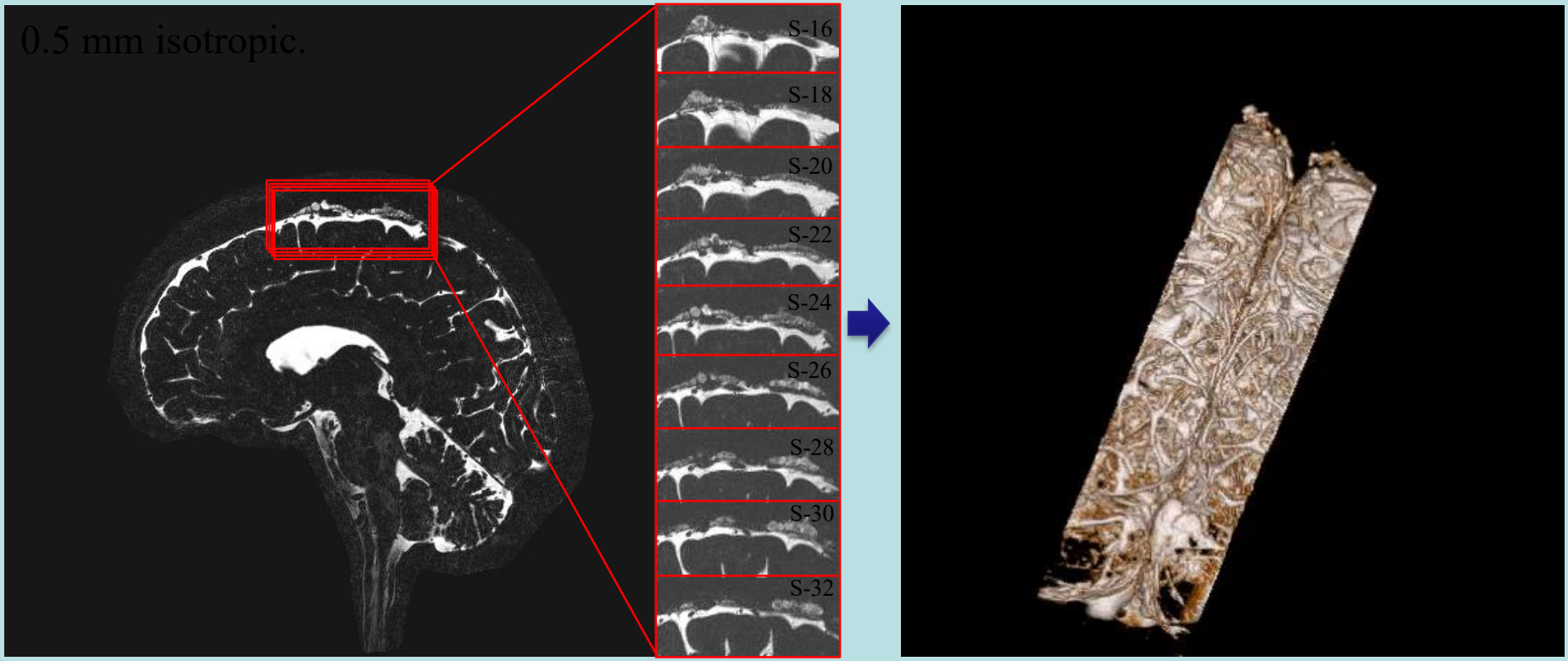
The subtraction between pre- and post black-blood scans after image co-registration (T1W-SPACE)

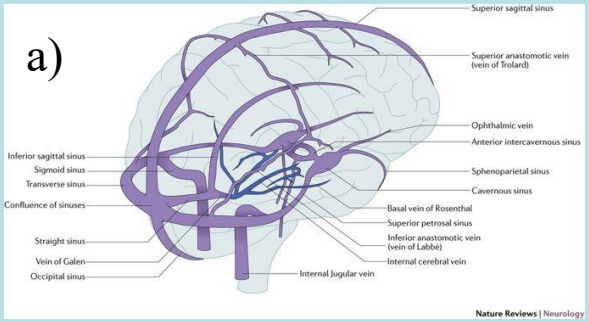
To view the MRI better in the dura better: CVO are removed



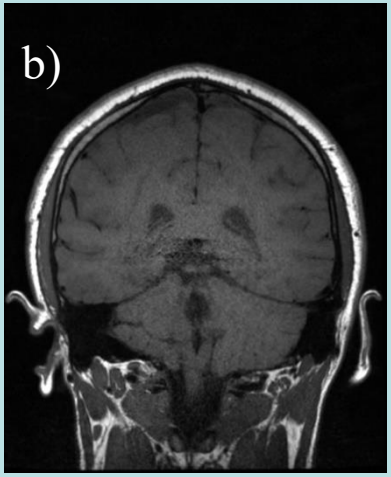
IV-injected Gd black-blood MRI after removing CVO

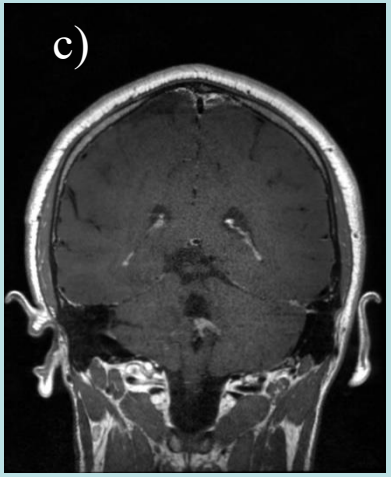
To understand the dura MRI better: High resolution in vivo CSF MRI (3D CSF MRI)

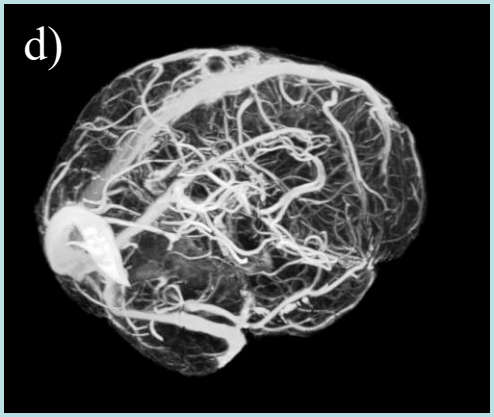


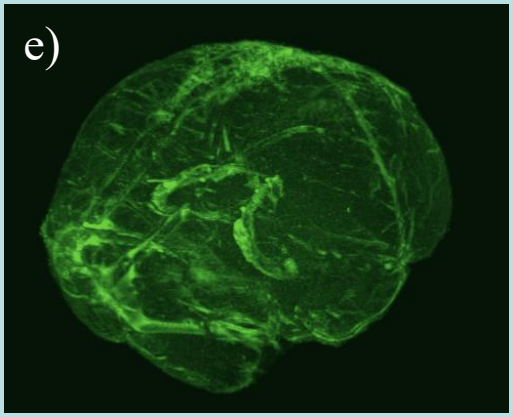


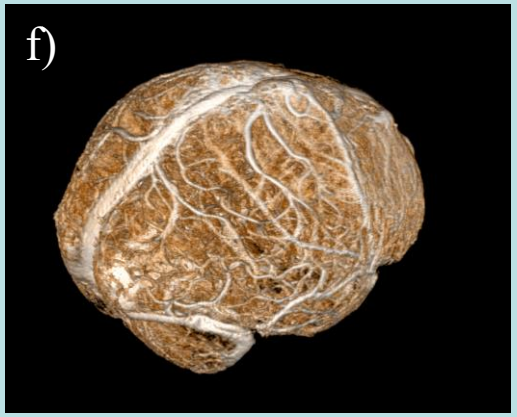
The superior sagittal sinus (SSS)











a. Brain venous anatomy; b and c were pre- and post black-blood MRI; e was the subtraction between pre- and post black-blood MRI after image co-registration; d and f were the subtraction between pre- and post bright-blood MRI.

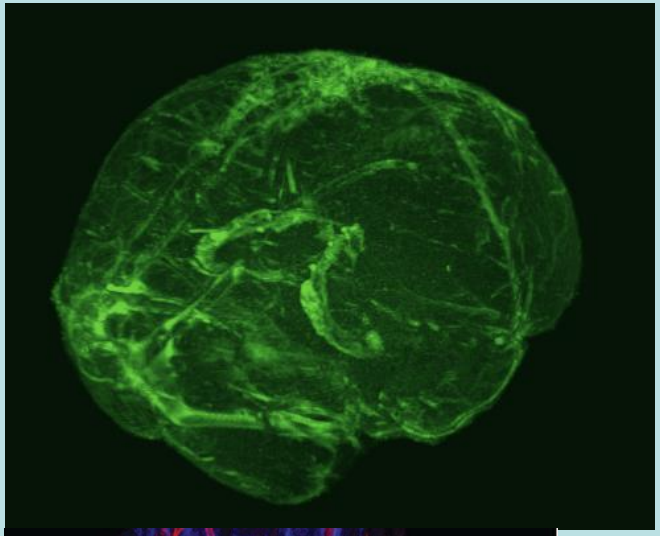
Key Results:

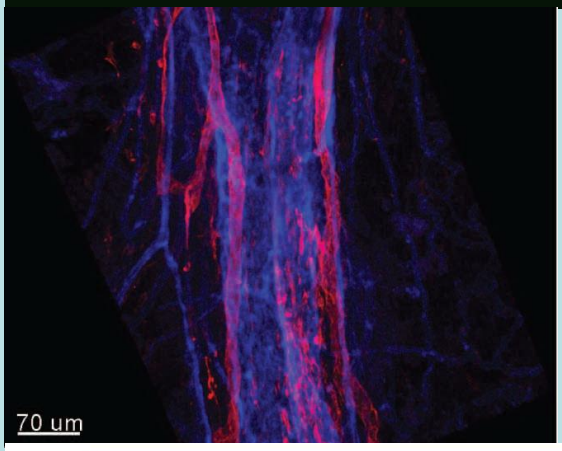
IV injected gadobutrol Black-blood MRI are Dural gap + Choroid Plexuses (CP) + CVO Or organs with naturally leaked vessels in the brain.

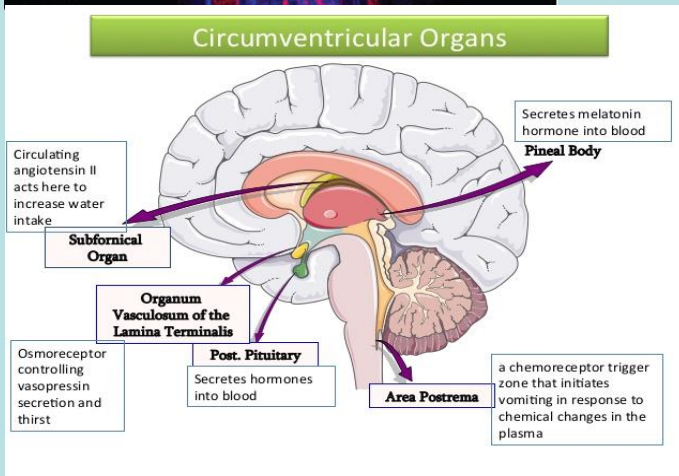
In other words, the Black-blood image in the dura **is not equal to** Dural lymphatic vessels;

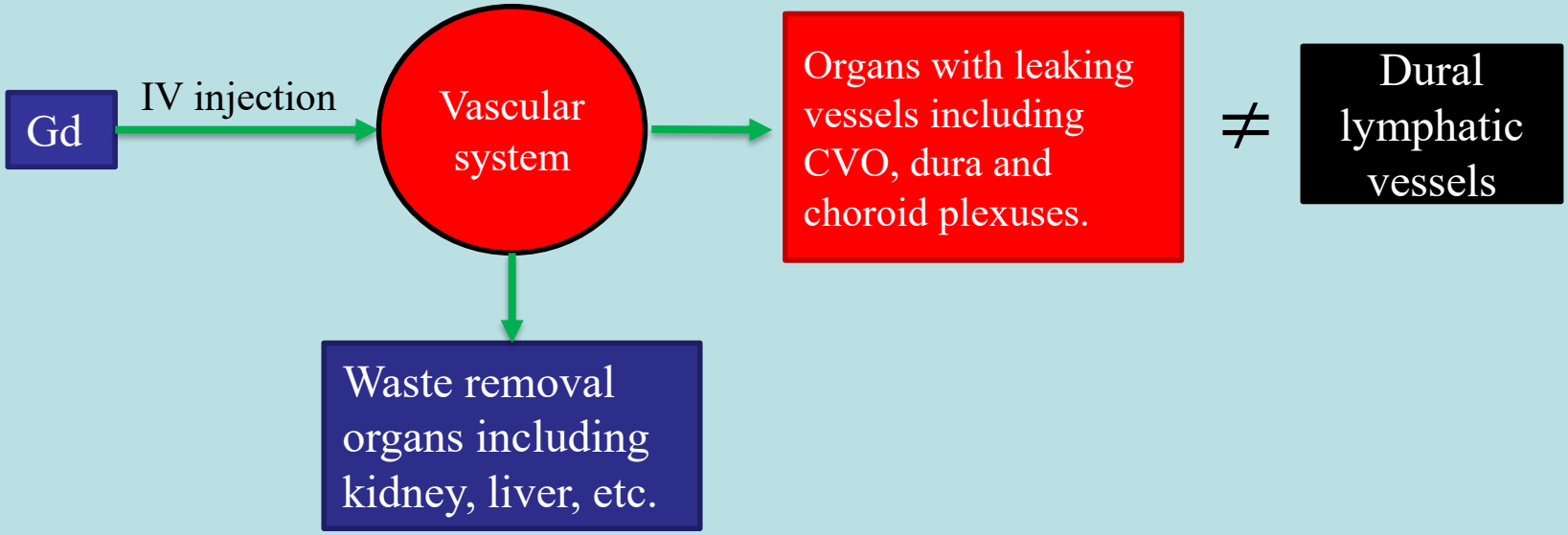
The histologic diameter of dural lymphatic vessel **is much smaller than** the MRI diameter of Black-blood "dural lymphatic vessels"

These black-blood MRI contains dural lymphatic vessels.








Gd
IV injection
Vascular system
Organs with leaking vessels including CVO, dura and choroid plexuses.
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Dural lymphatic vessels
Waste removal organs including kidney, liver, etc.

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