Quantitative MRI

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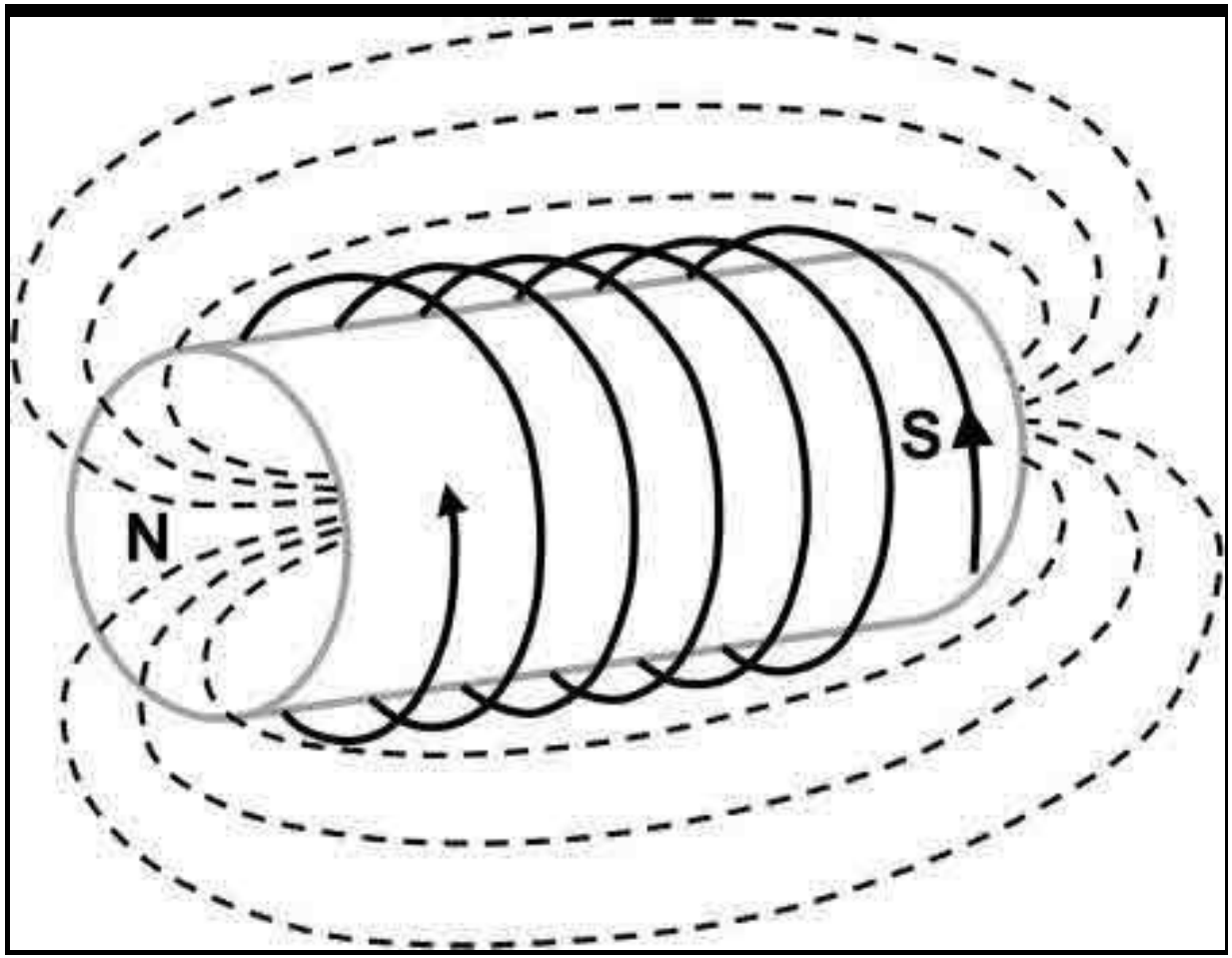
Fellowship of Neuroimmunology
and Multiple Sclerosis

SIEMENS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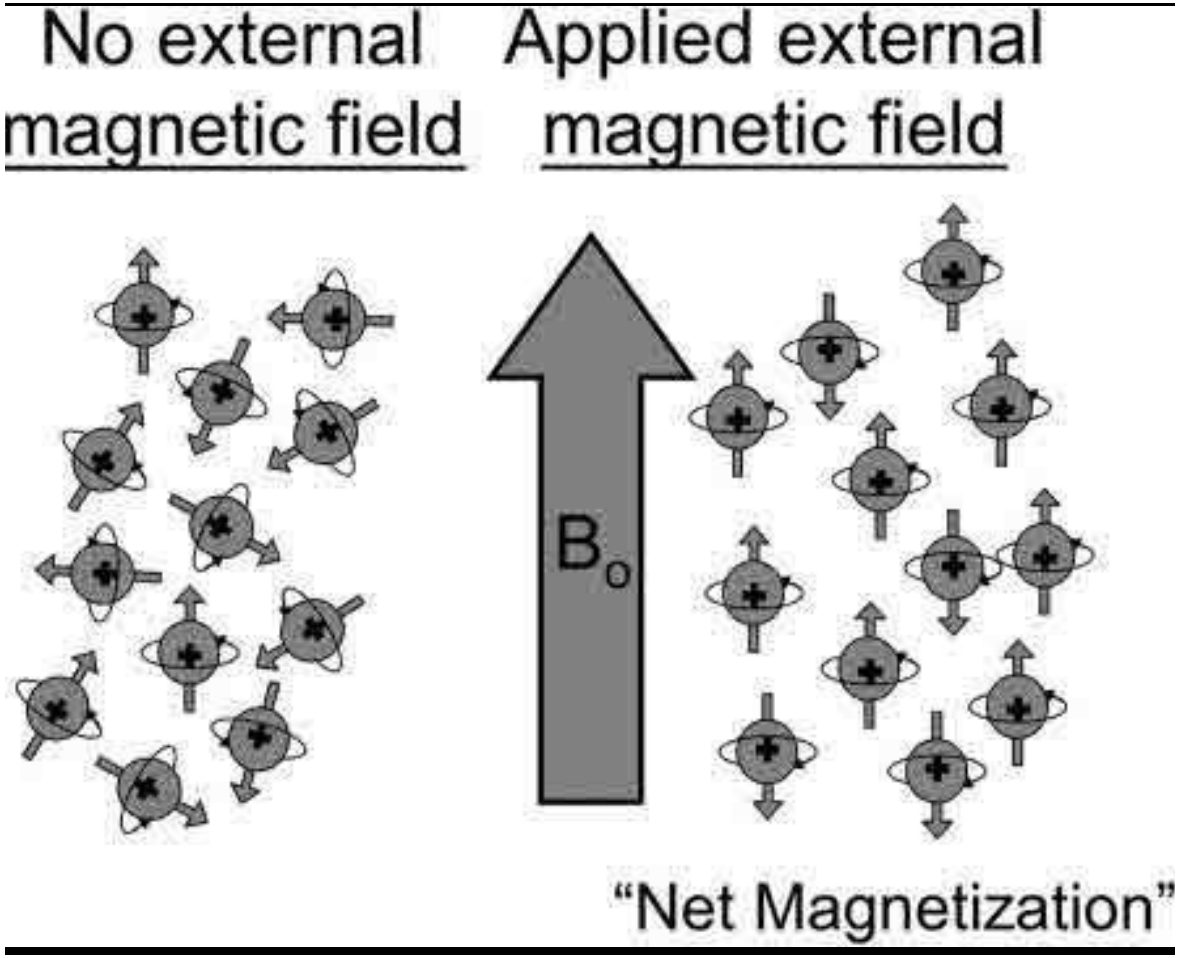
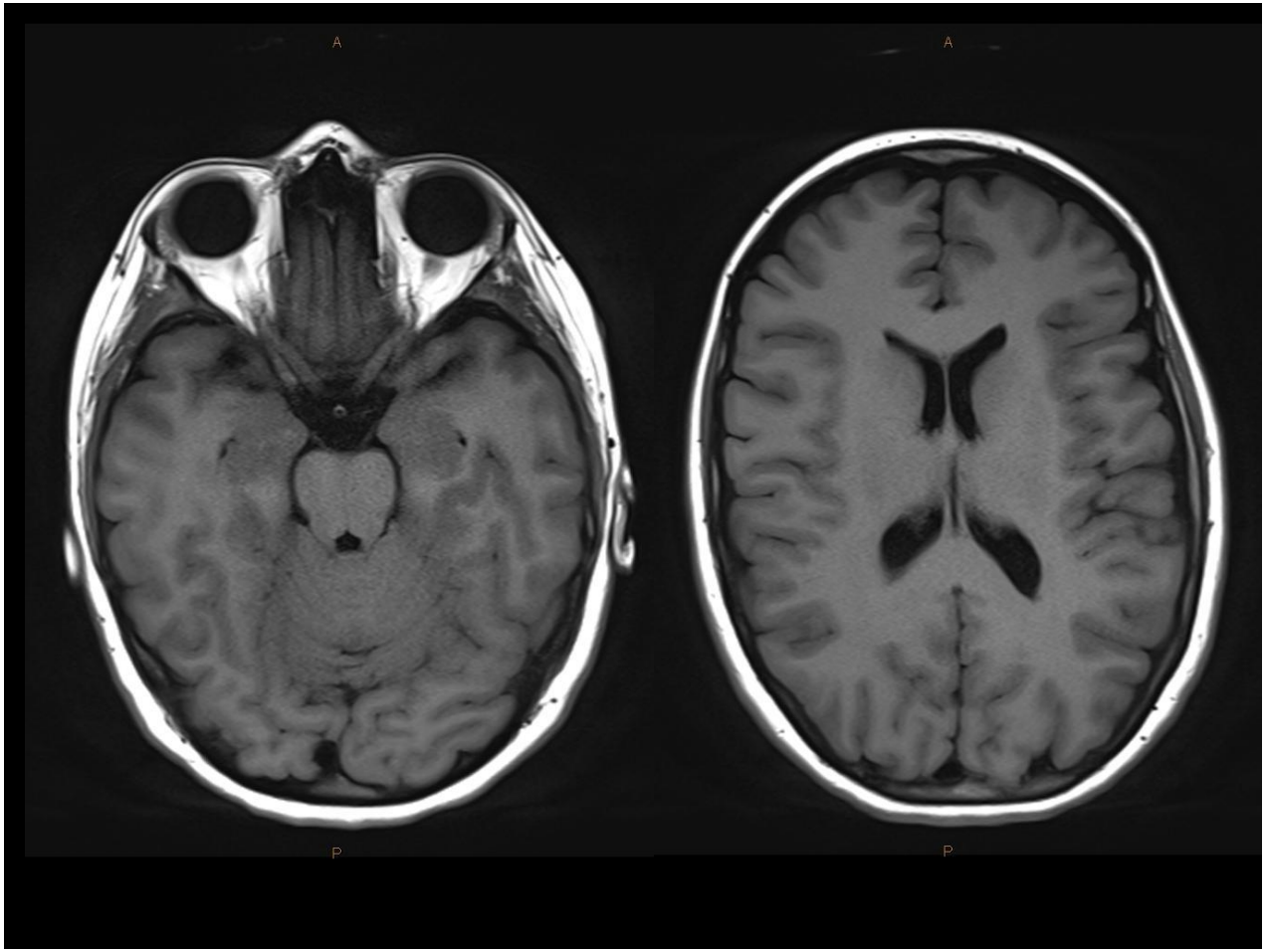

No external magnetic field
Applied external magnetic field
B_o
"Net Magnetization"

- Radio-waves are then produced to diphase protons.
- Timing and strength of waves can be manipulated to produce different tissue weighting characteristics.


A
A
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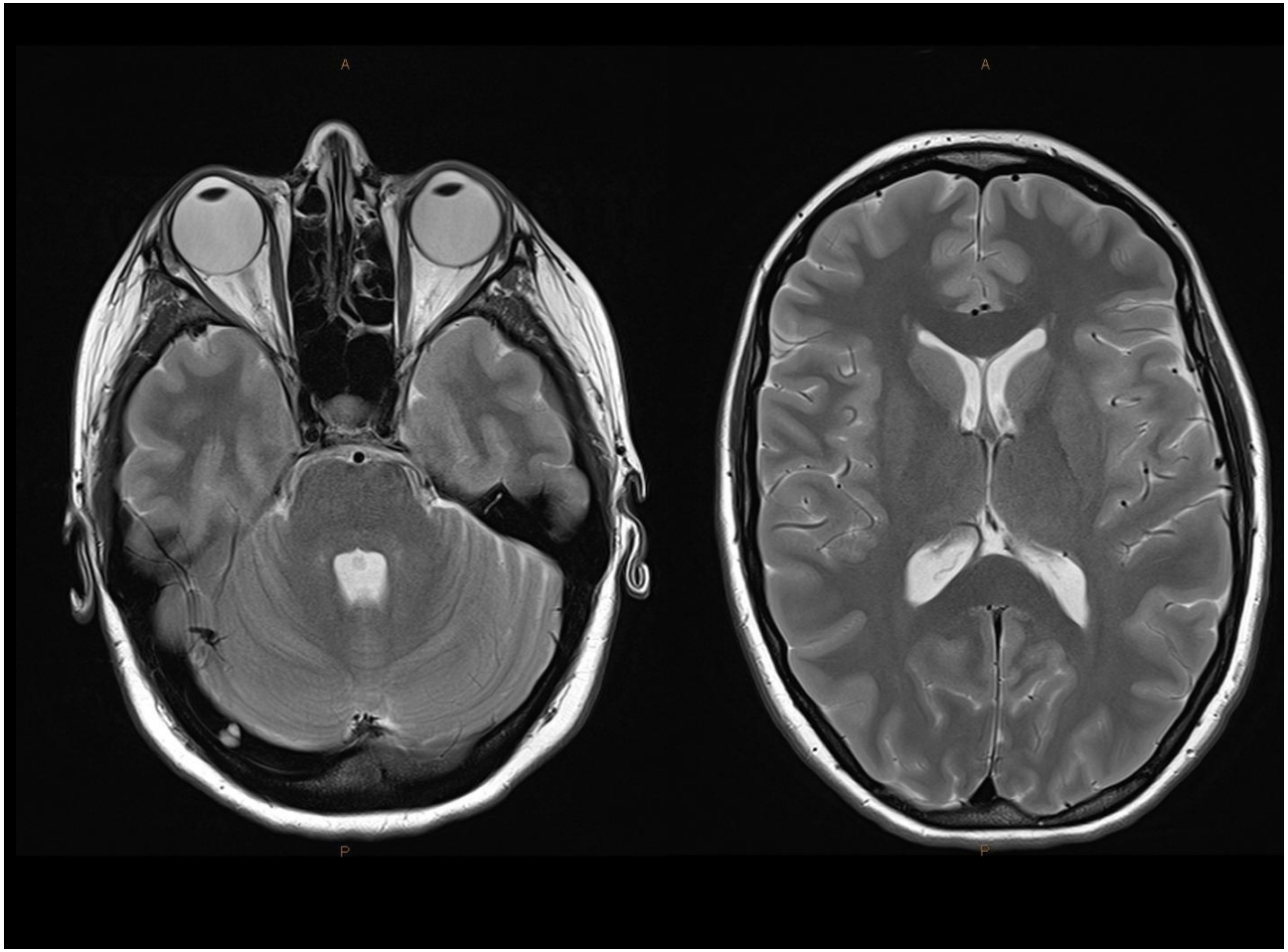
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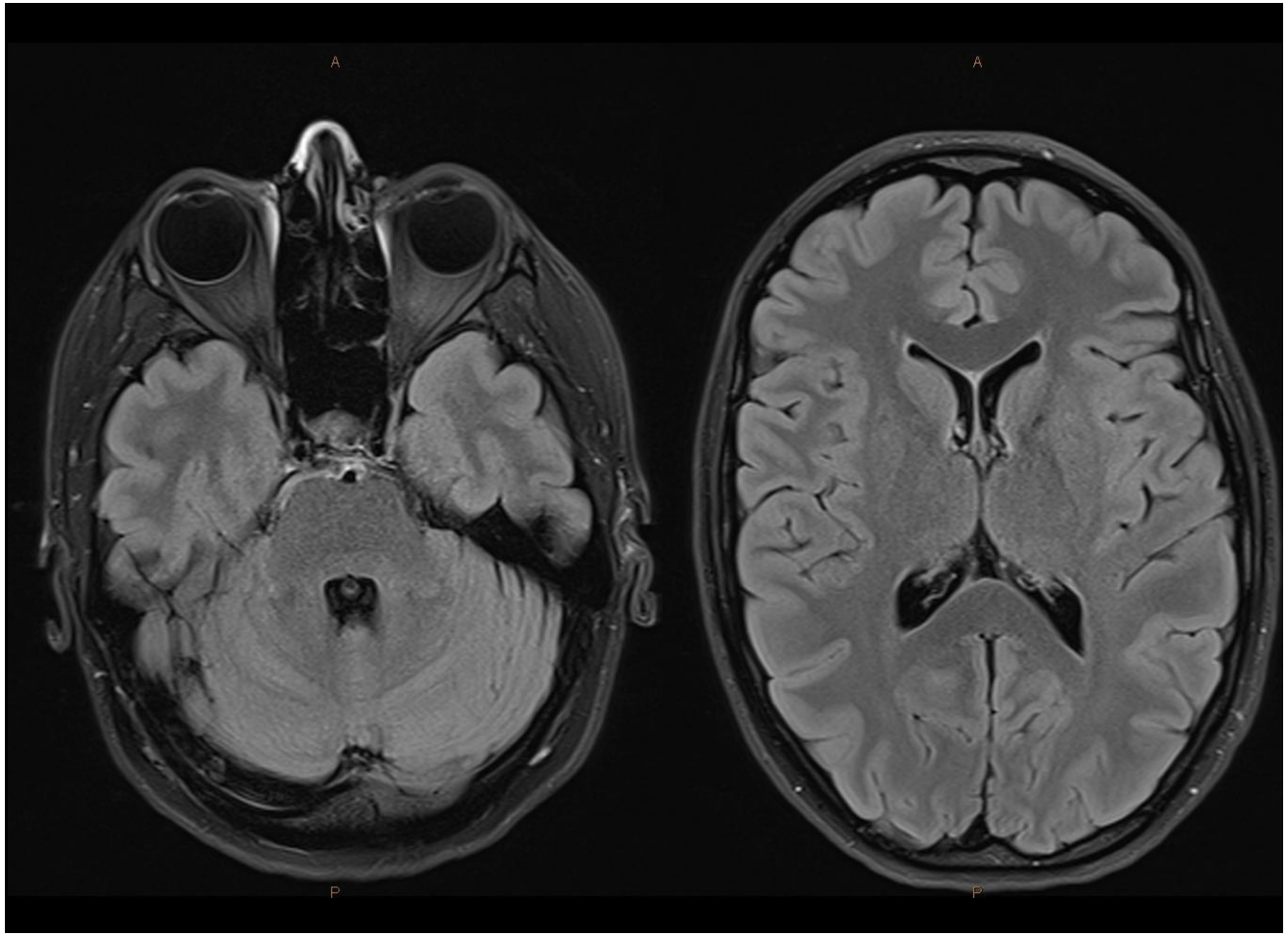
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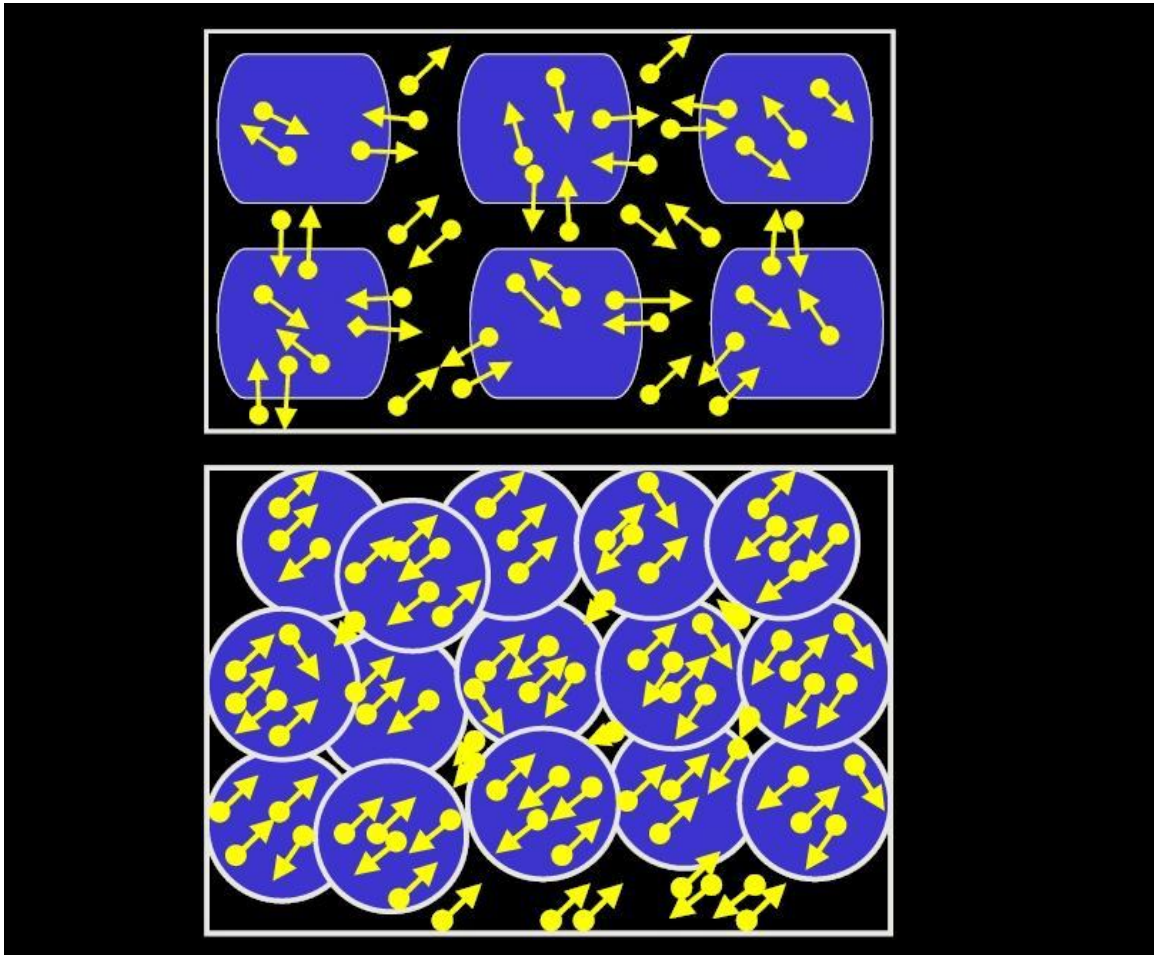

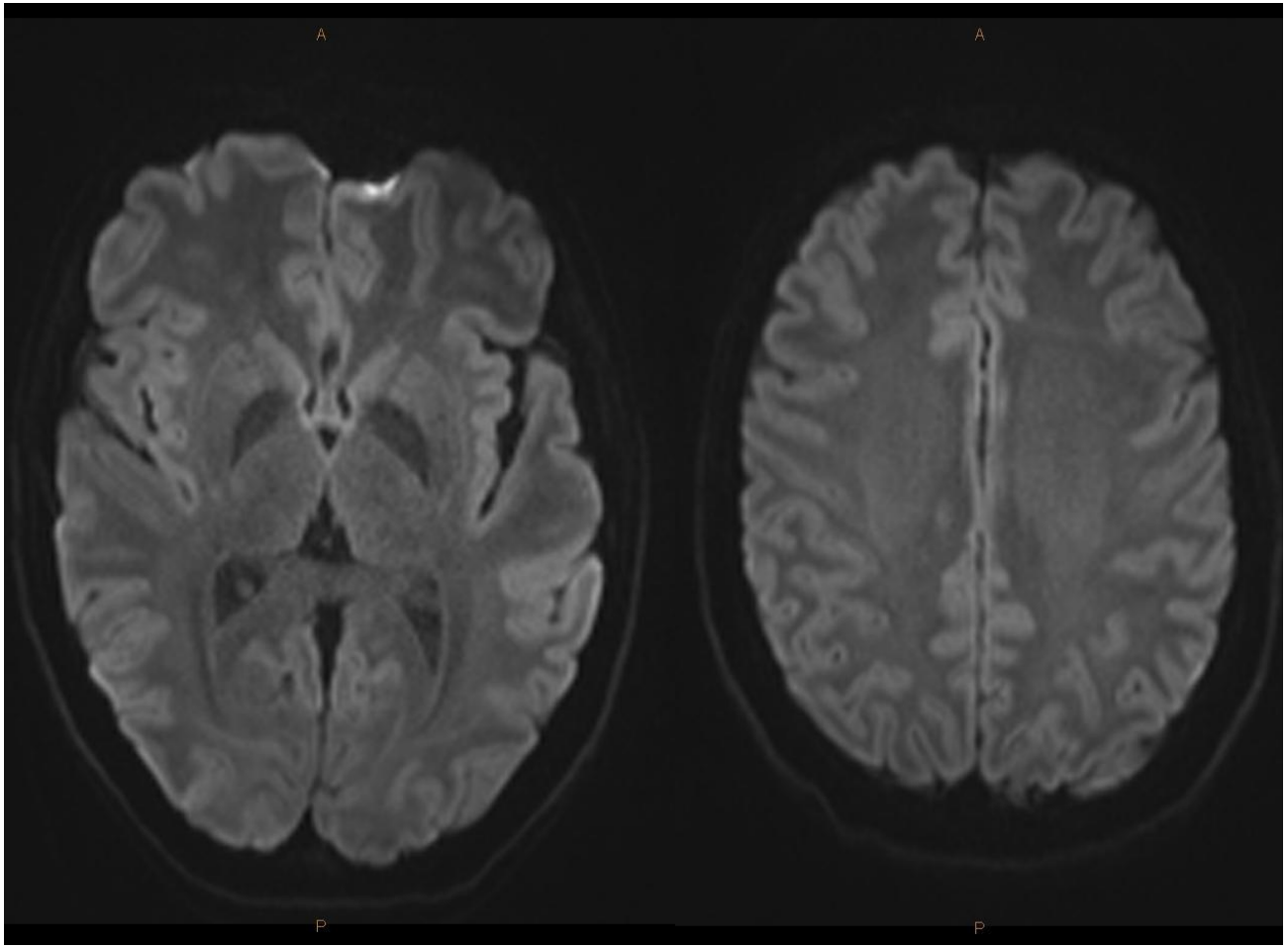
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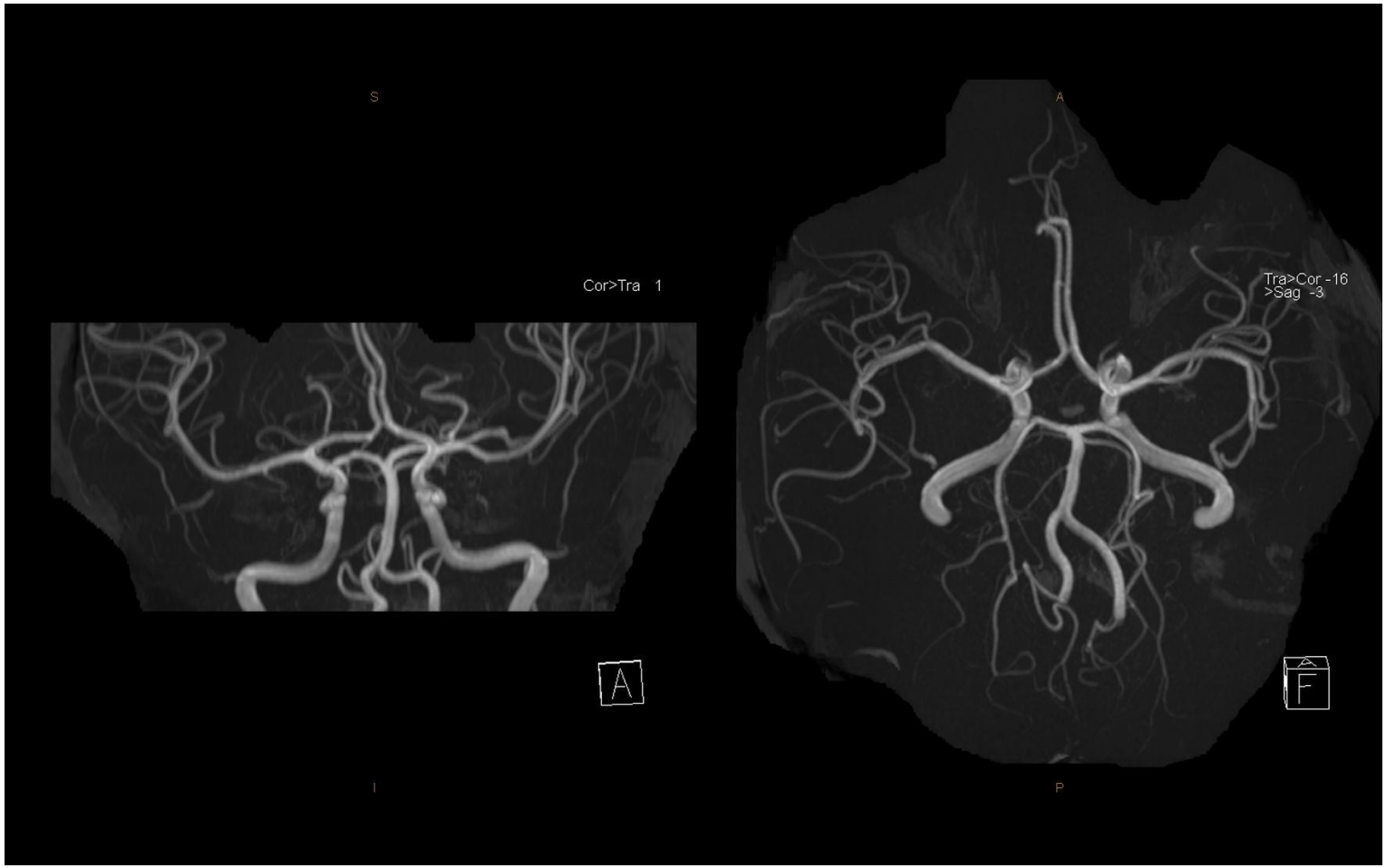
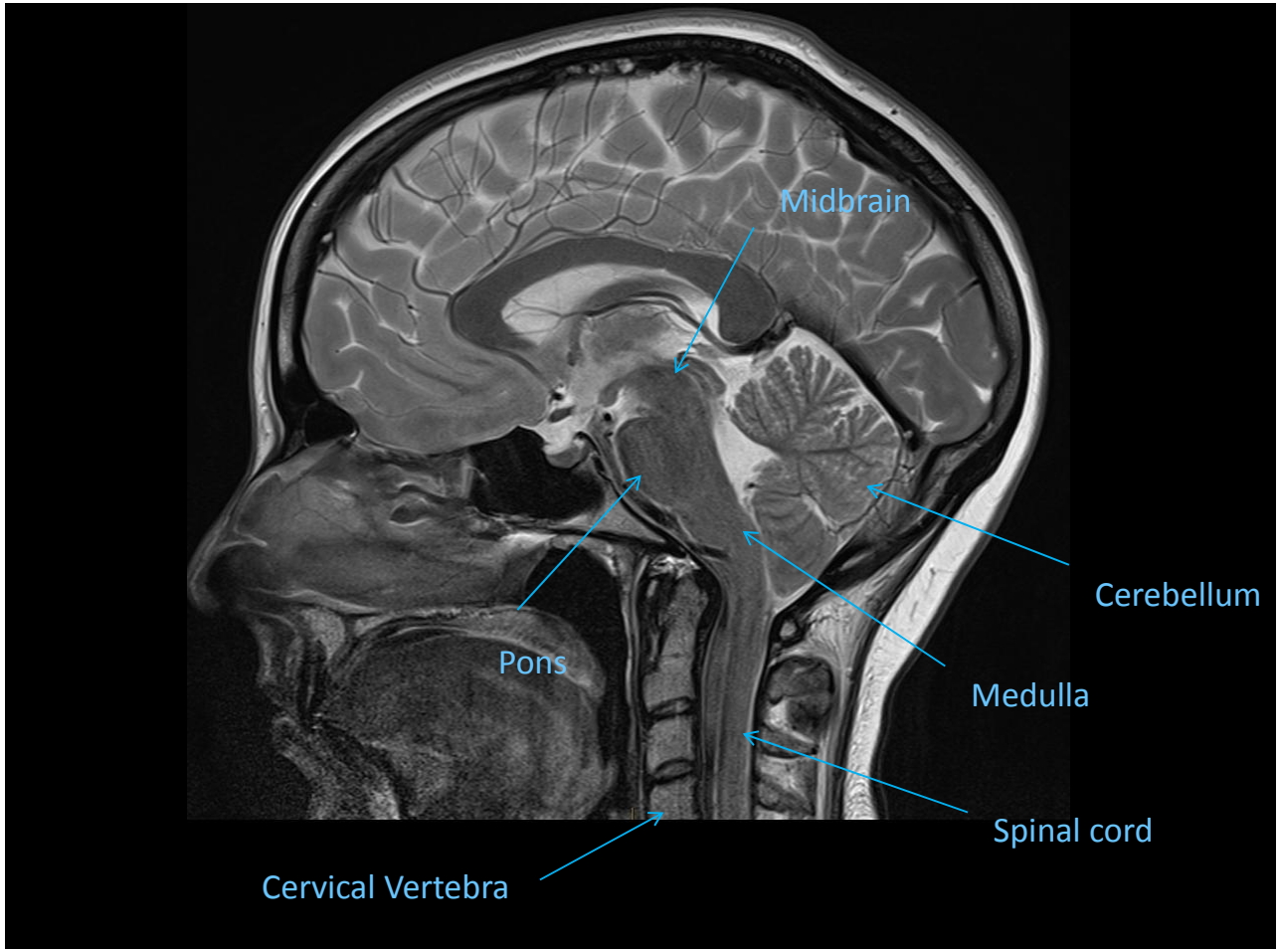
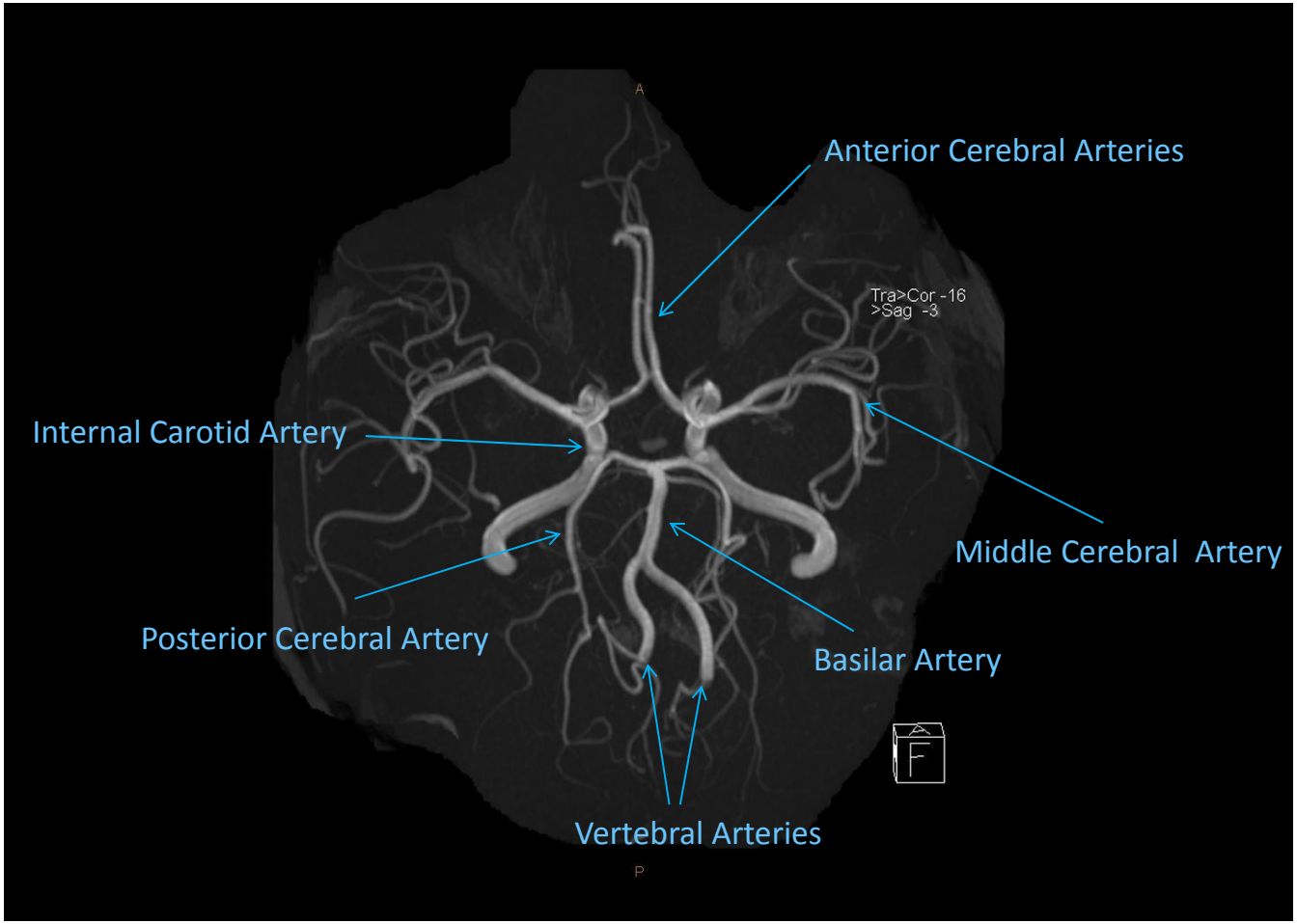
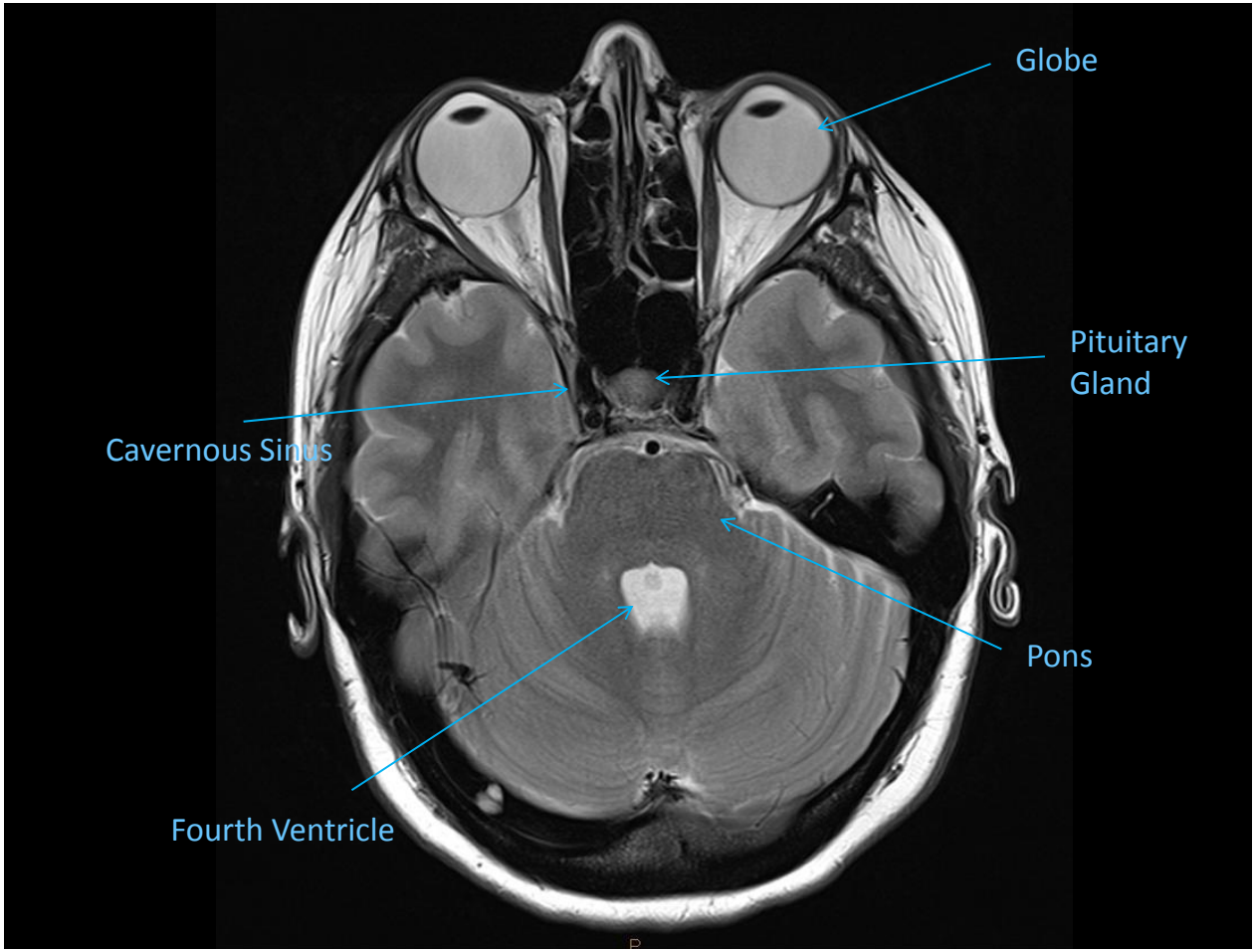
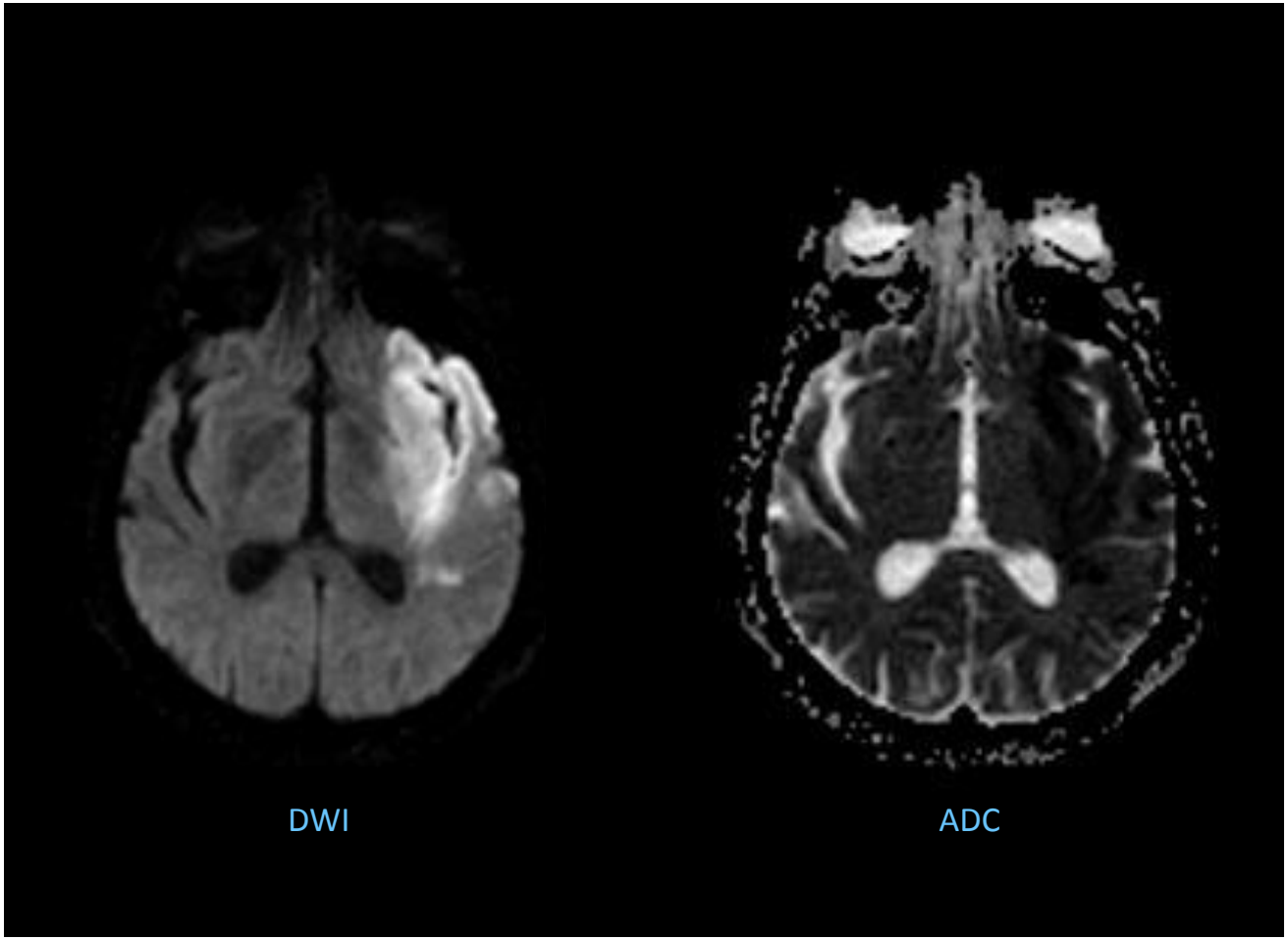
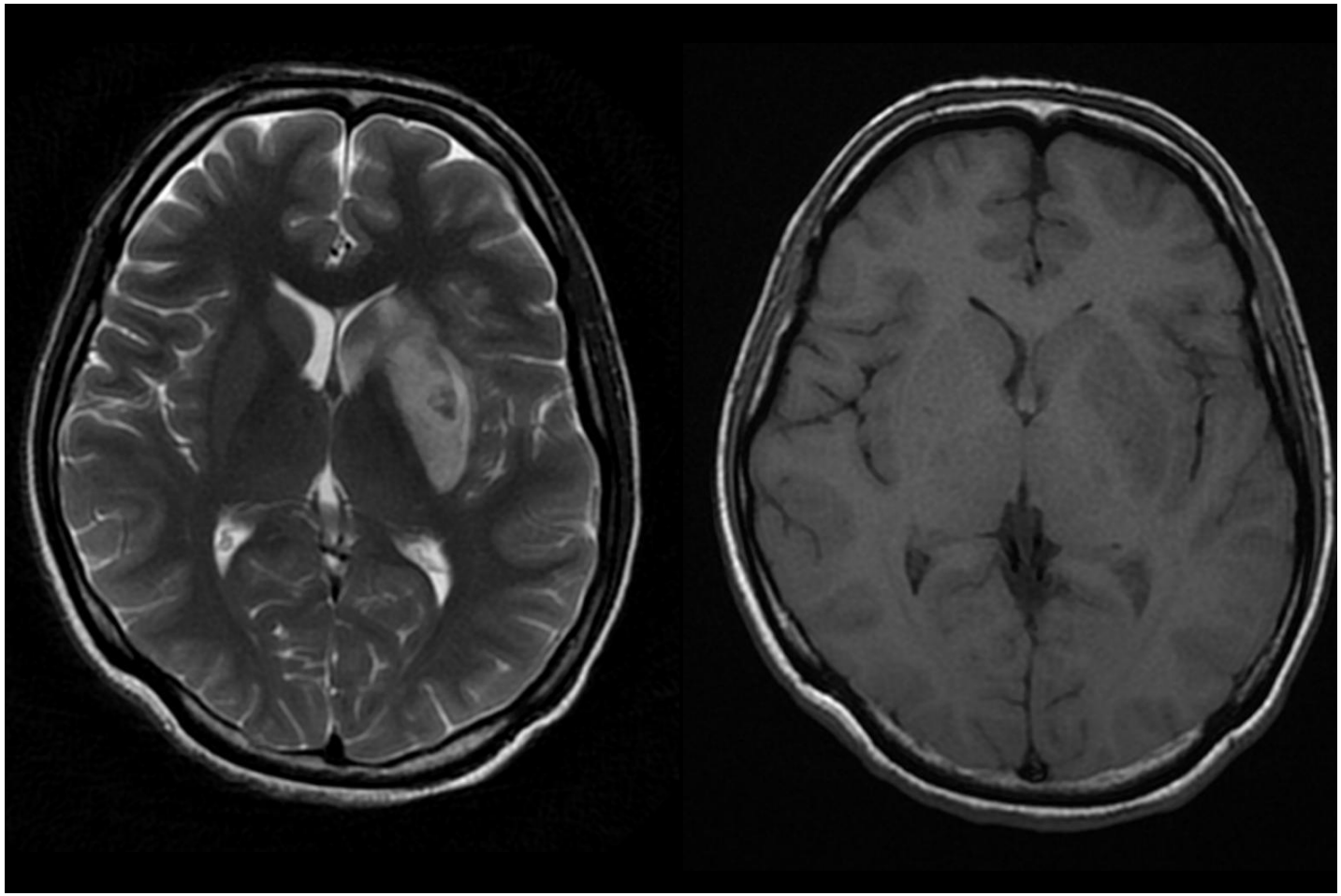

S
Cor>Tra 1
A
I
A
Tra>Cor -16
>Sag -3
F
P

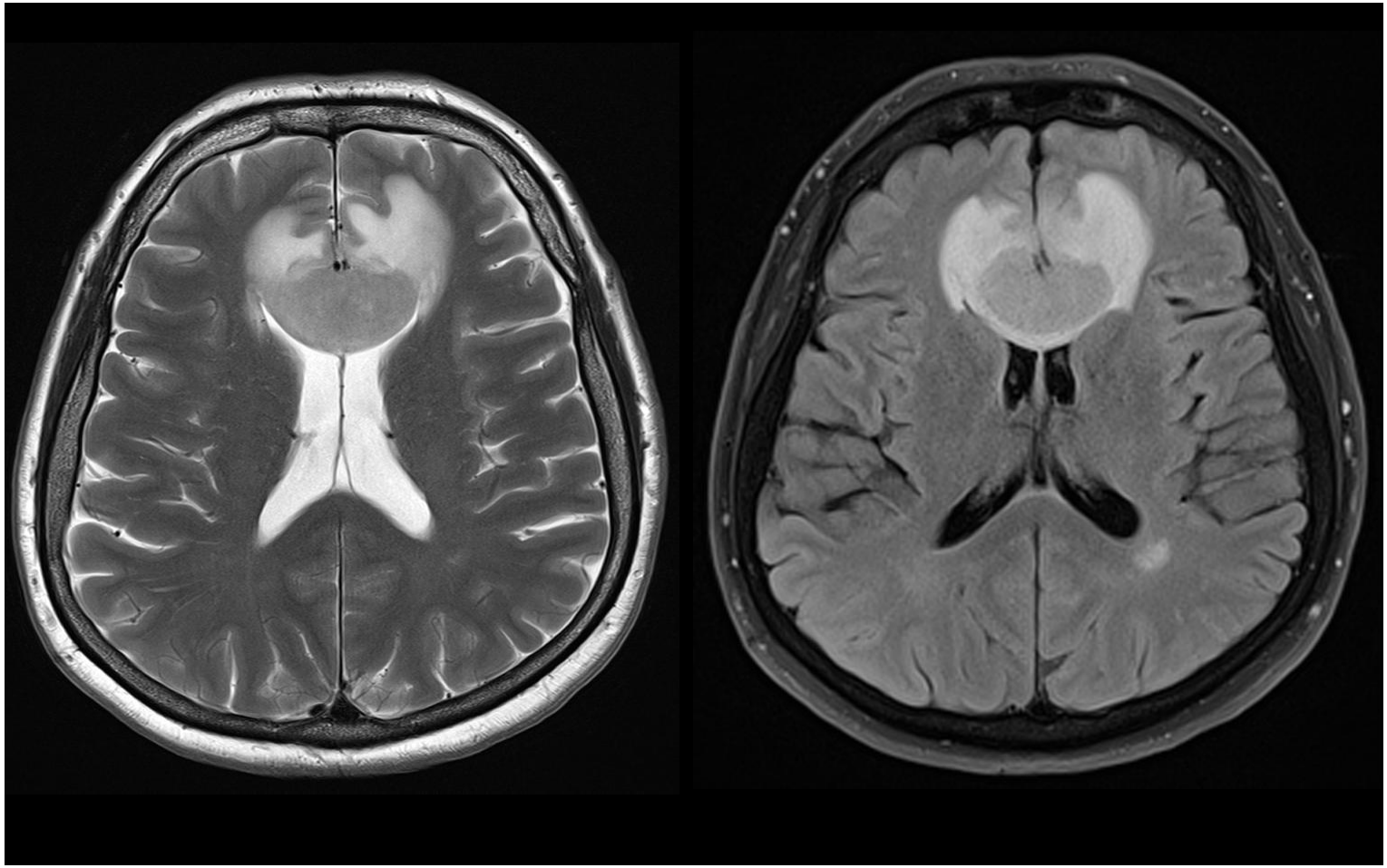

Midbrain
Cerebellum
Pons
Medulla
Spinal cord
Cervical Vertebra

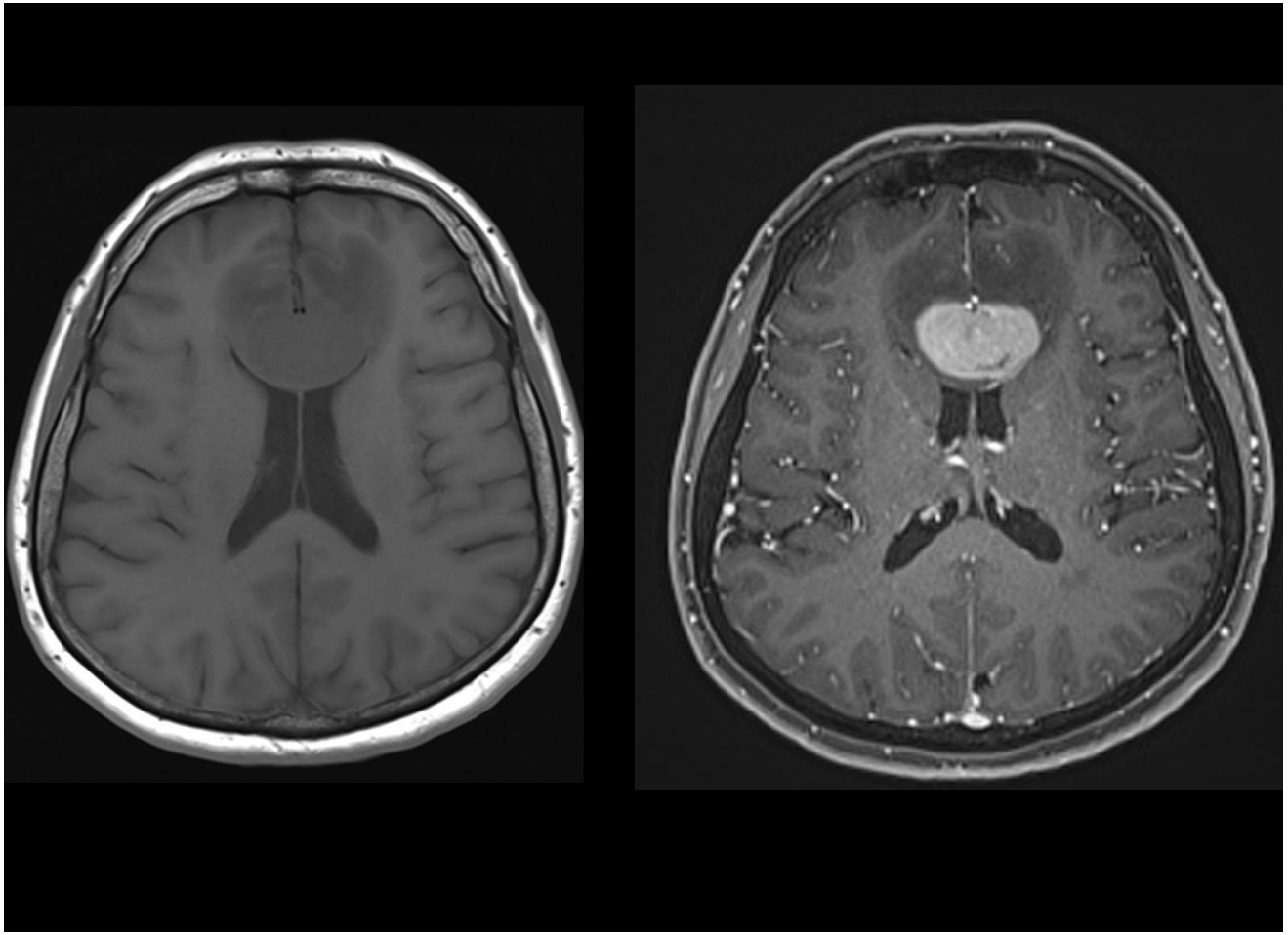

Anterior Cerebral Arteries
Internal Carotid Artery
Middle Cerebral Artery
Posterior Cerebral Artery
Basilar Artery
Vertebral Arteries
A
P
Tra>Cor -16
>Sag -3

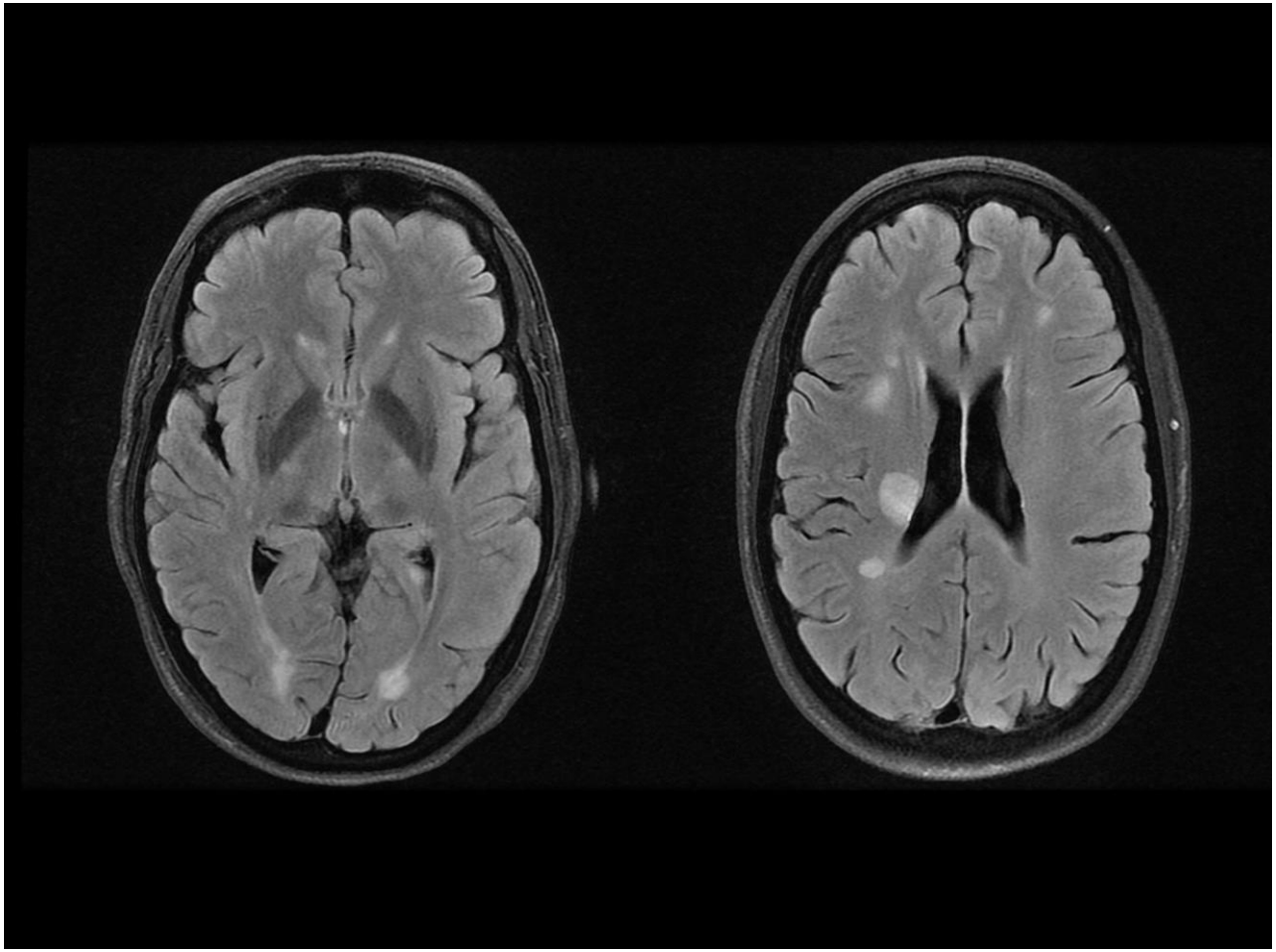

Globe
Pituitary Gland
Cavernous Sinus
Pons
Fourth Ventricle

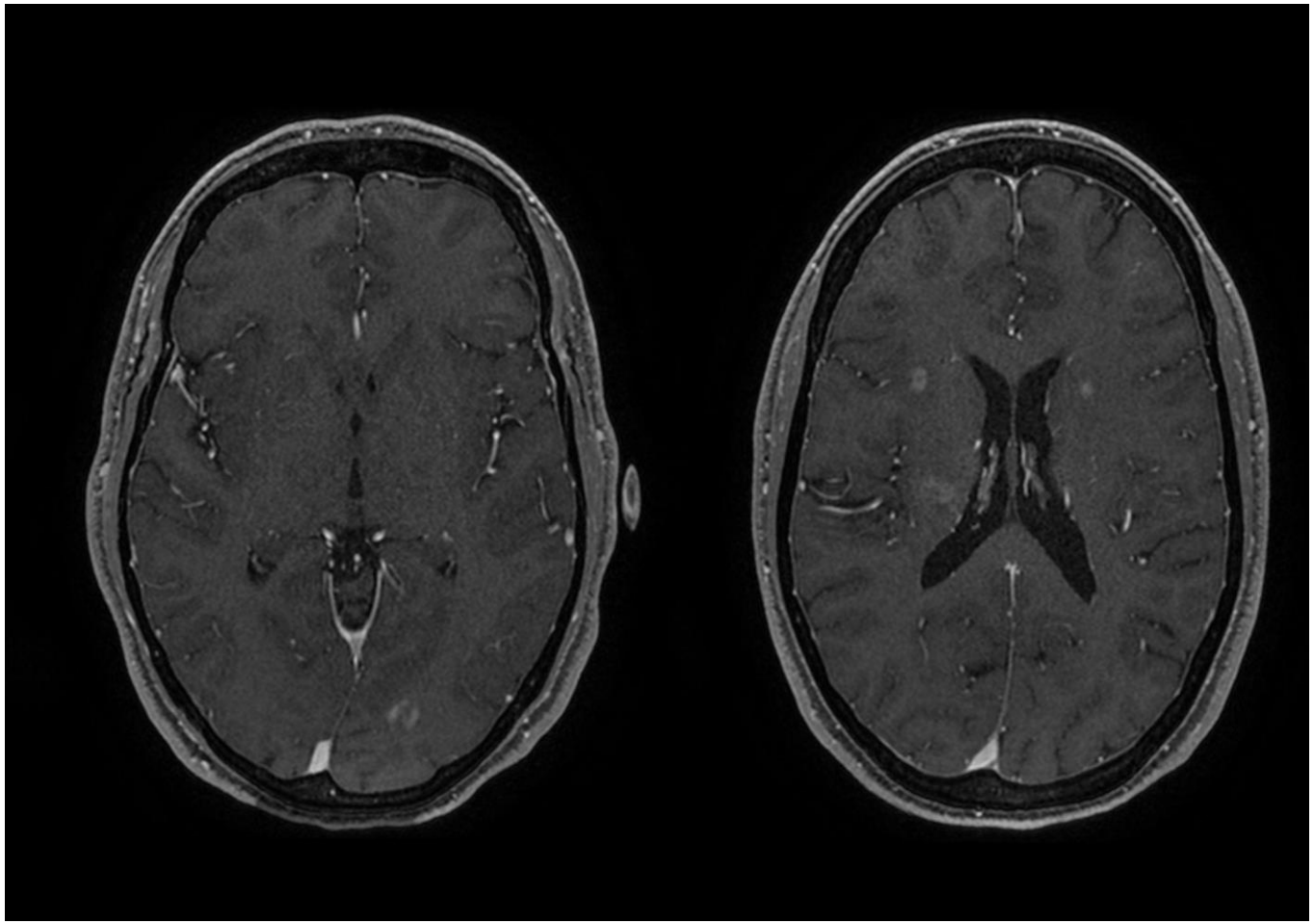

DWI
ADC

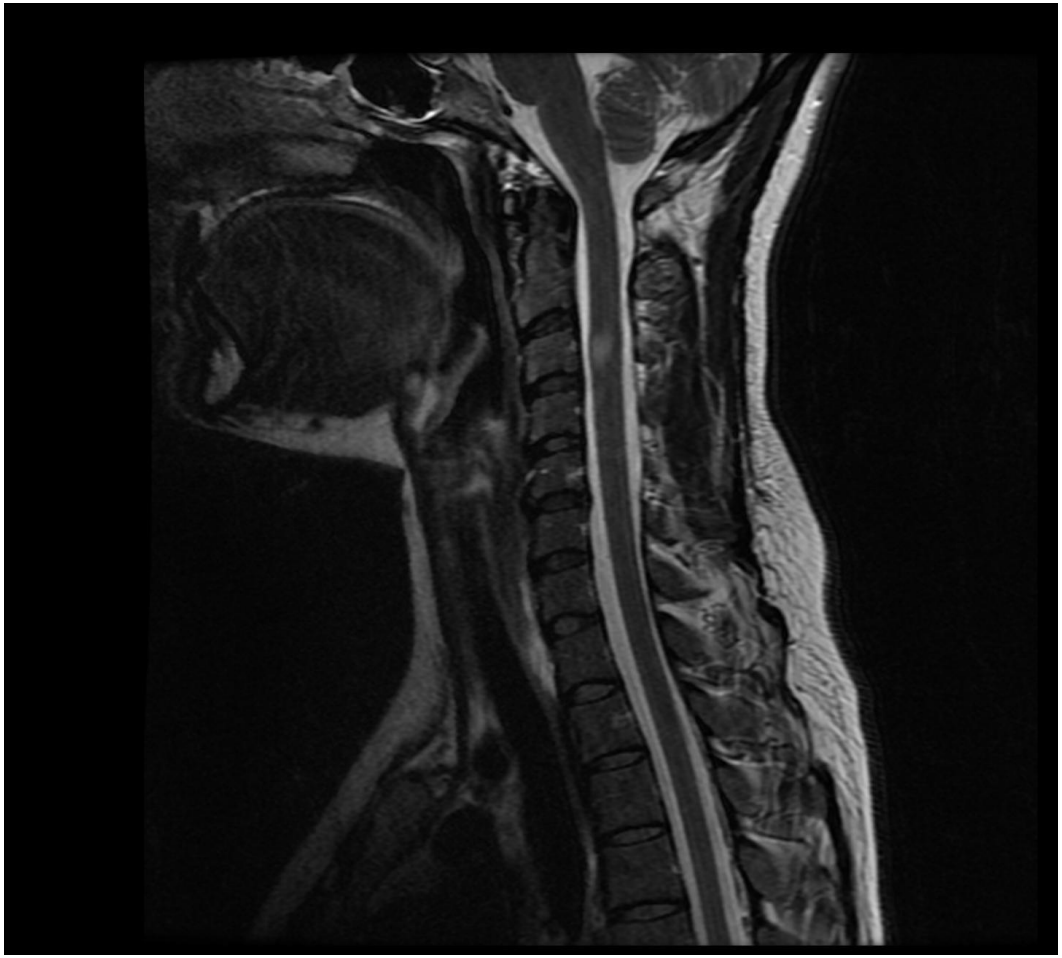








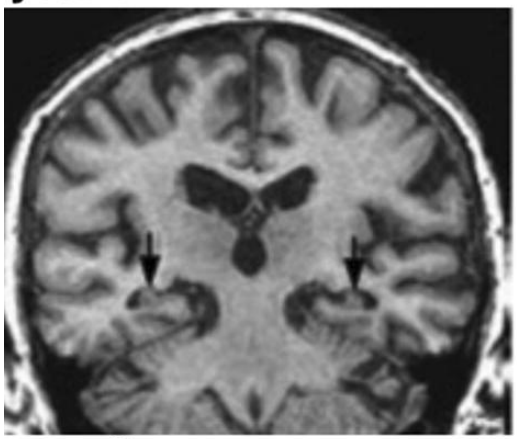




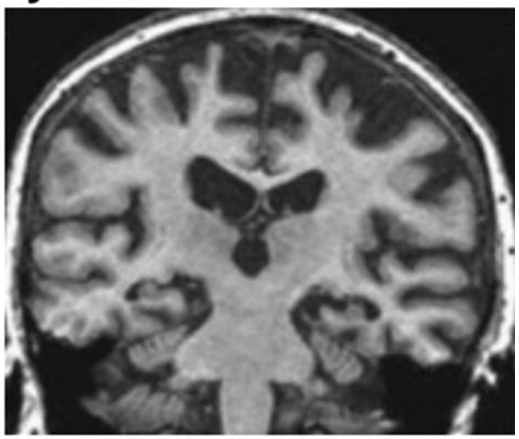
Quantitative Analysis of Conventional Imaging

- MRI scanner is no longer seen as a camera, but a scientific measuring instrument.
- notions of accuracy (closeness to the truth, characterised by systematic error) and precision (repeatability, or random error) become relevant.

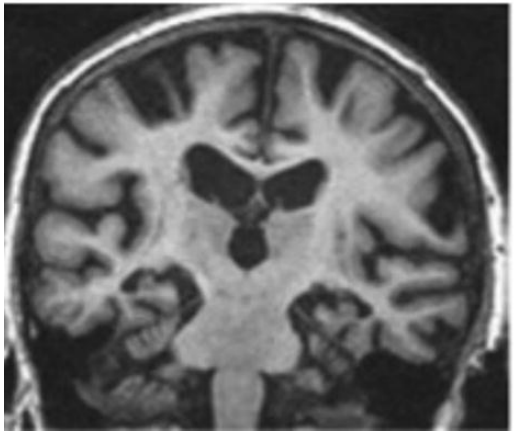
year 1



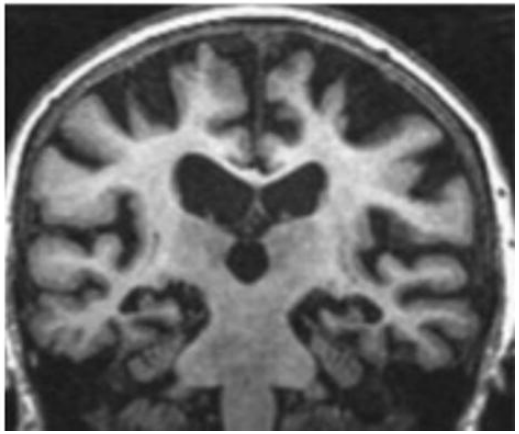
year 2

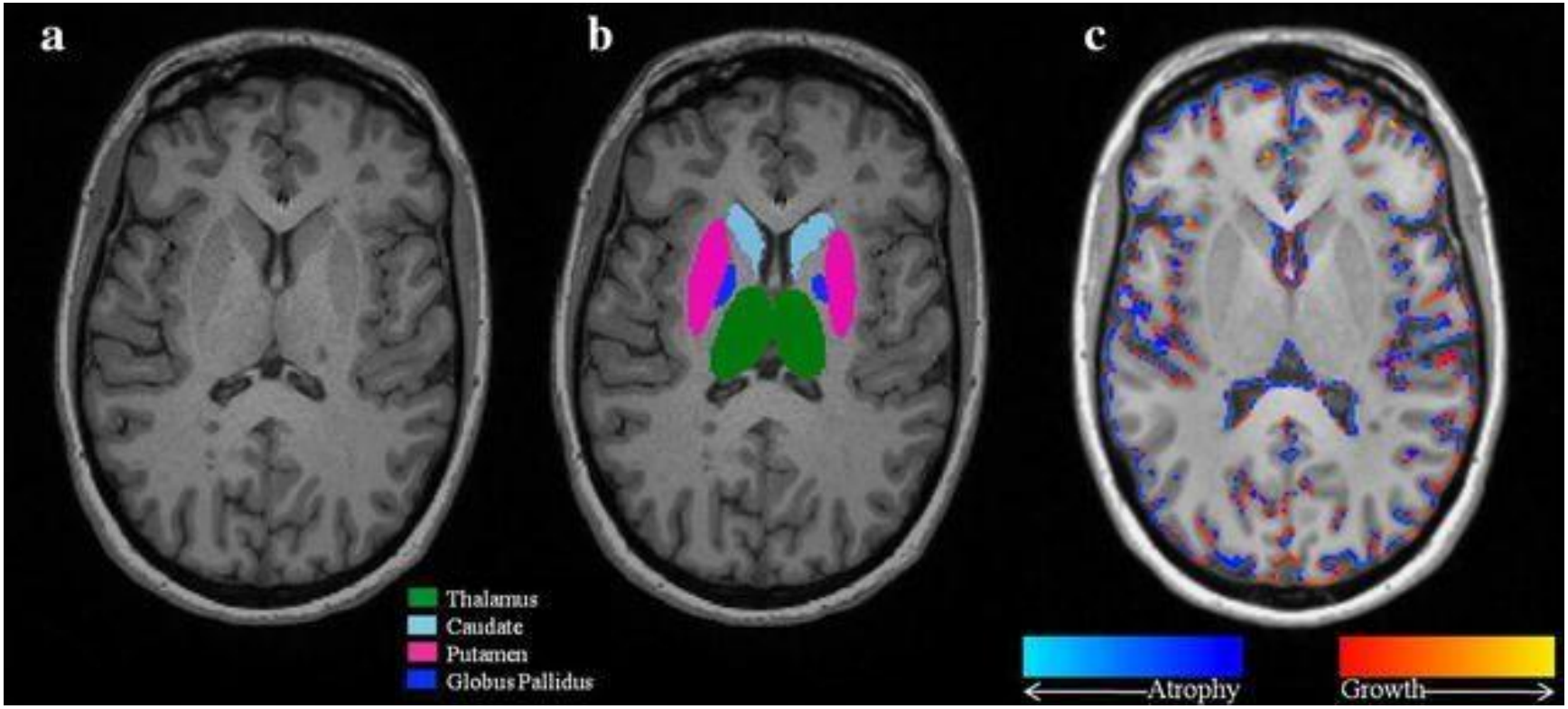


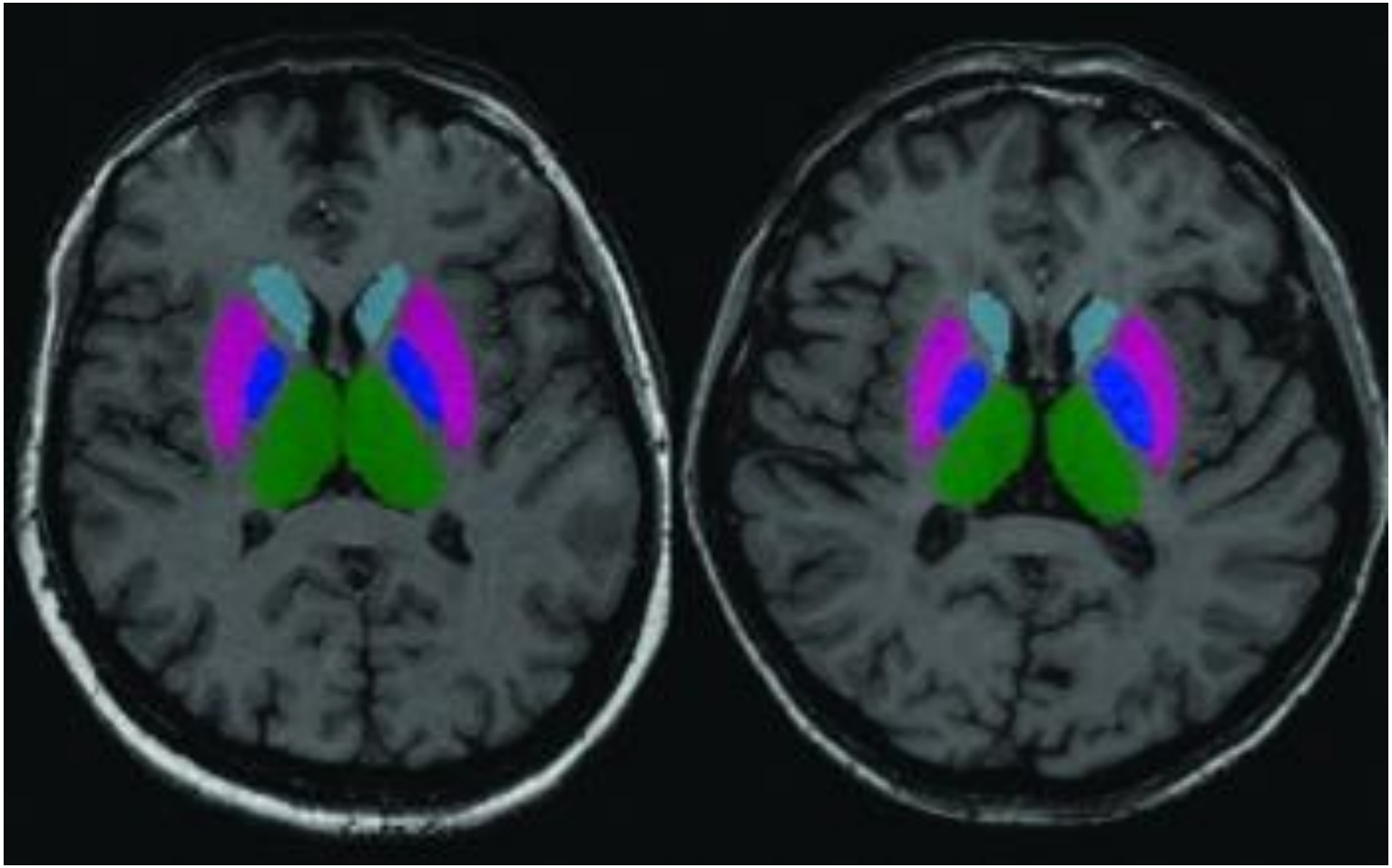
year 3

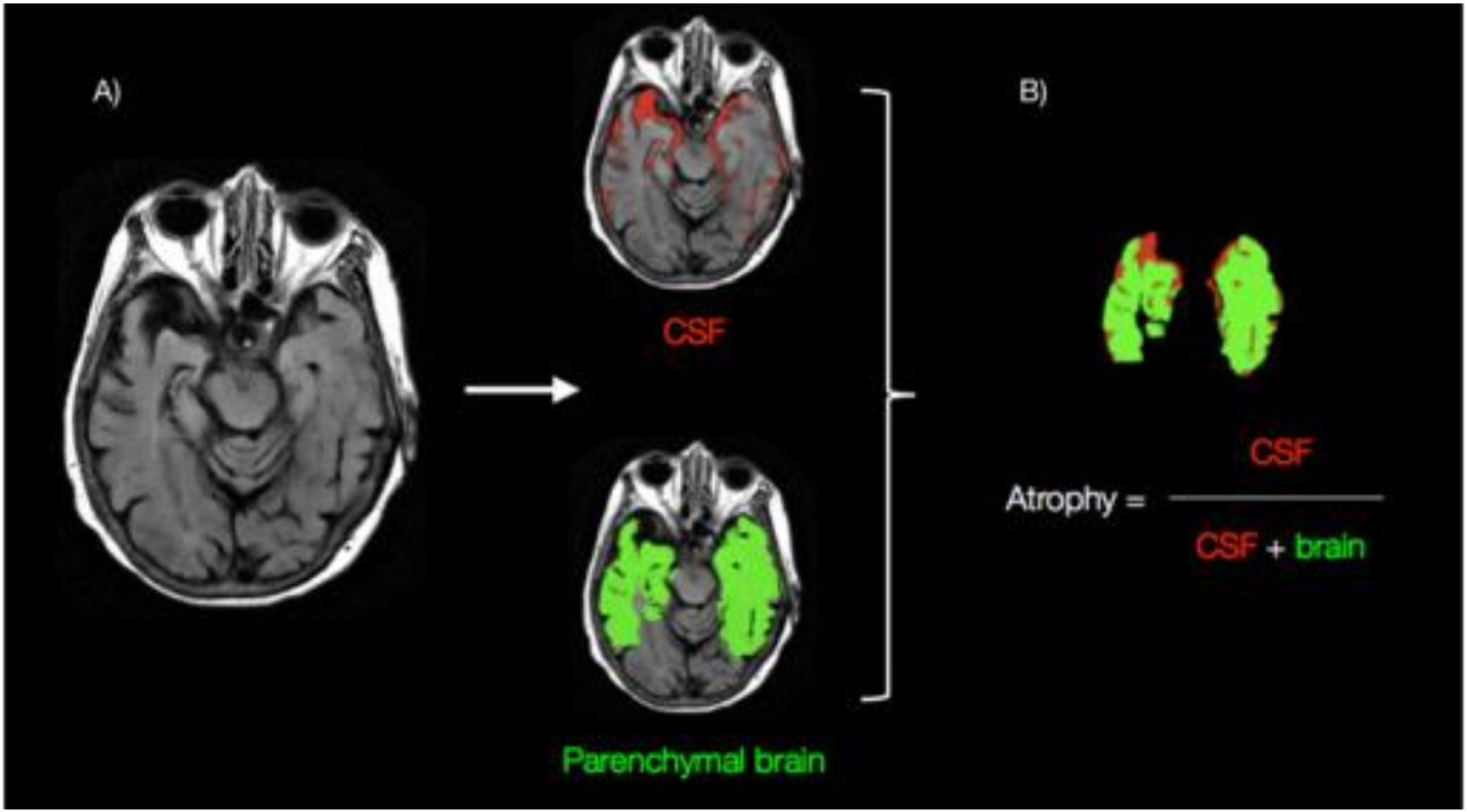


year 4



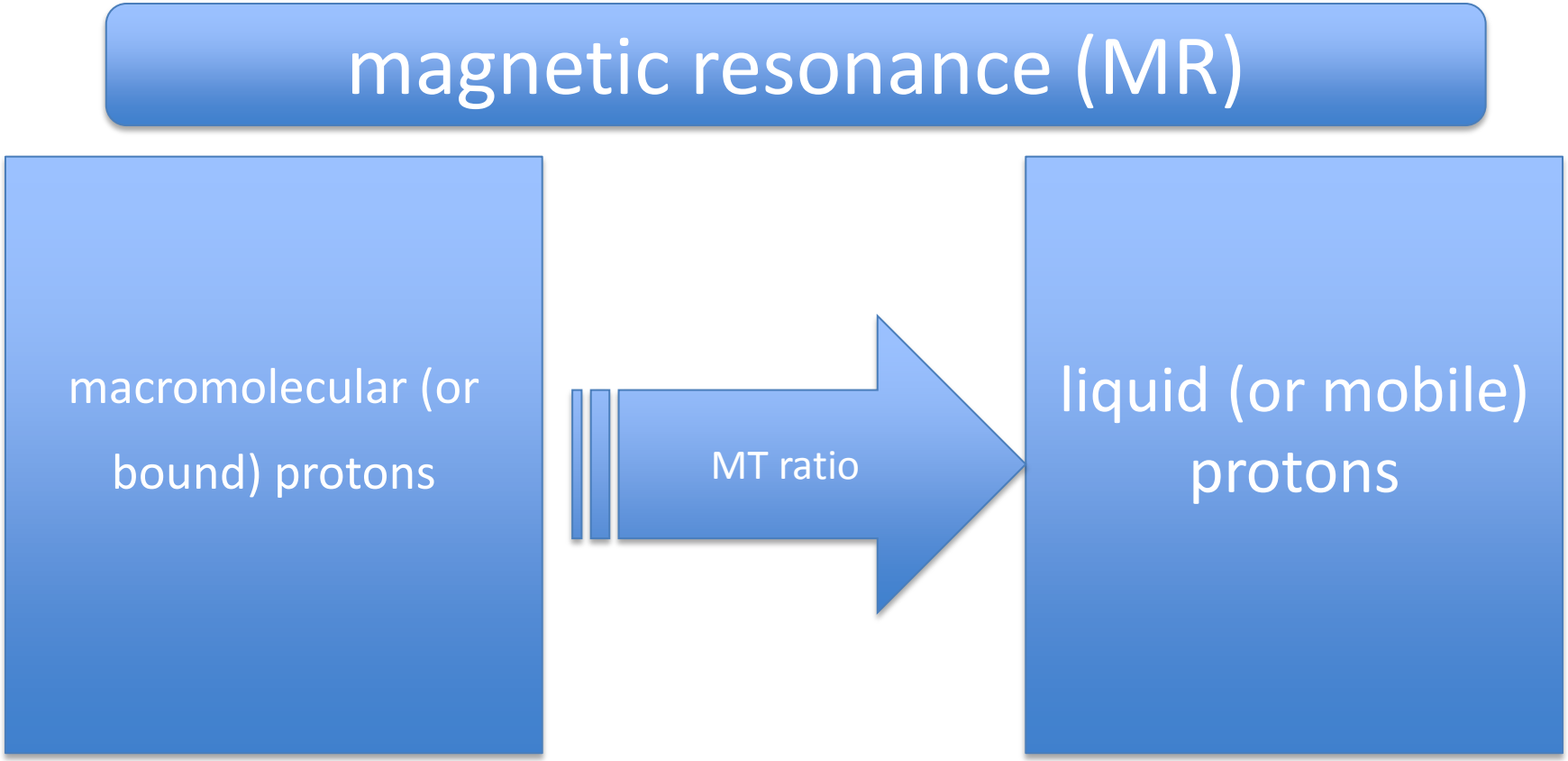

a
b
c
Thalamus
Caudate
Putamen
Globus Pallidus
Atrophy
Growth




A)
CSF
Parenchymal brain
B)
Atrophy = CSF / CSF + brain

- quantitative lesion measures
  - new lesions
  - changes in overall lesion burden
- Volumetric measurements
  - Regional atrophy
  - Spinal Atrophy
  - Whole Brain Volume

Magnetization transfer imaging



(MTR = 100*[MToff – MTon]/Mtoff)

- Decreased in MTR prior to the appearance of a WM lesion on T2-weighted MRI or Gadolinium (Gd)-enhanced T1w MRI suggests early myelin pathology not detectable by conventional MRI
- The evolution of MTR within new lesions varies from lesion to lesion: mean lesional MTR may recover over 1–5 months, suggesting remyelination; or, it may remain low or decrease further suggesting on-going demyelination

Diffusion Tensor Imaging

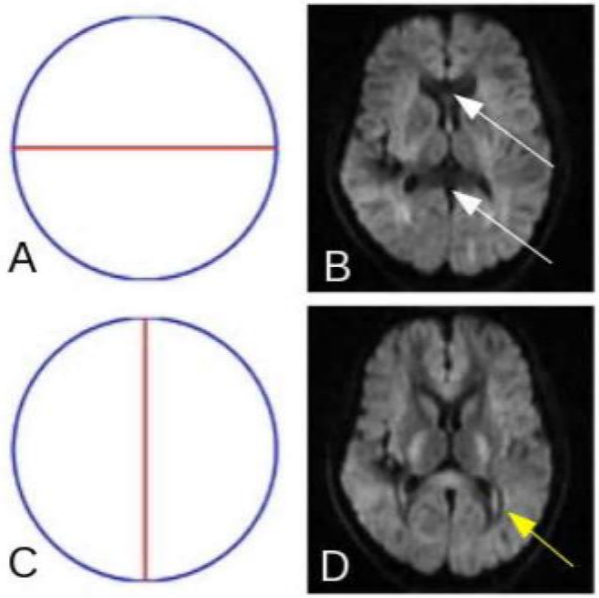


Figure 2.
An illustration of the contrast induced by diffusion weighting gradients (DWG). When the DWG is aligned left-to-right (A), signal attenuation is greatest in regions with highly organized bundles of myelin aligned left right (B, arrows. When the DWG is aligned anterior-to-posterior (C), signal attenuation is greatest in regions with myelin sheaths aligned anterior posterior (D, arrow).

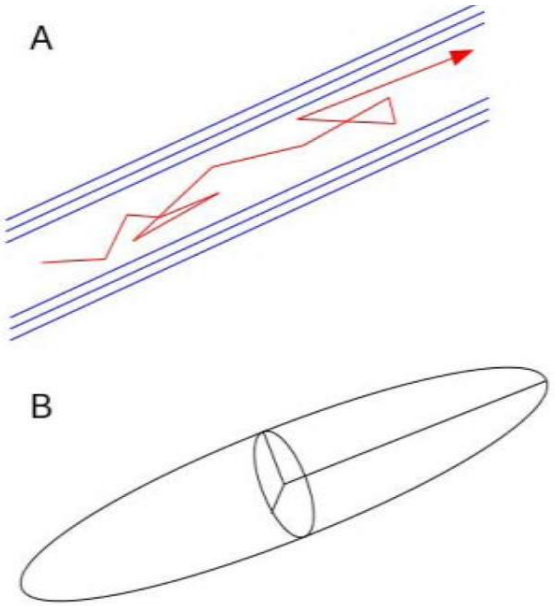
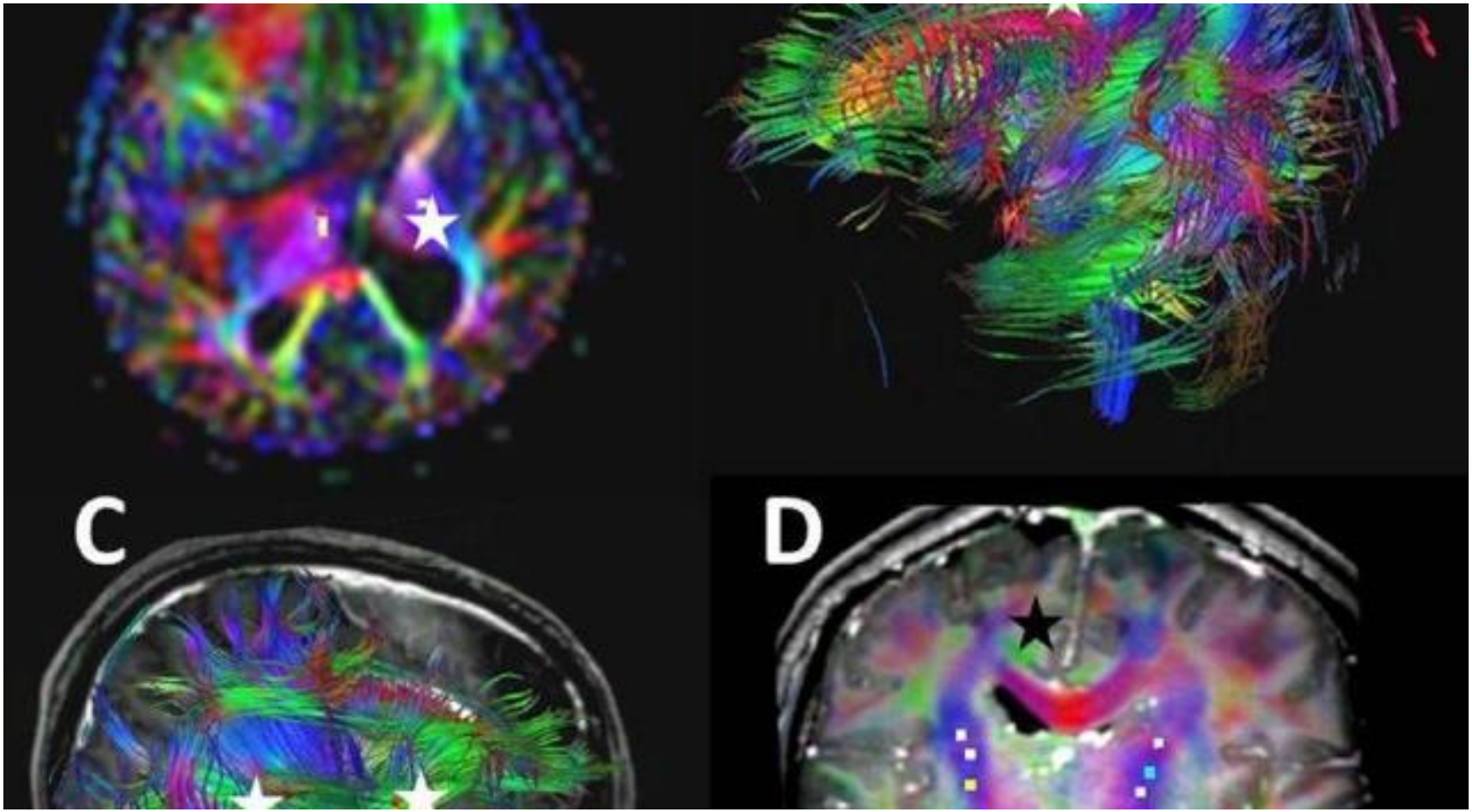


Figure 3.
(A) Cartoon of an axon with myelin sheaths (blue). A water molecule diffusing in this environment follows a path with movement preferentially aligned along the myelin sheath (red arrow). (B) Diffusion ellipsoid representation of diffusion tensor, with long axis aligned with preferred direction of water diffusion.

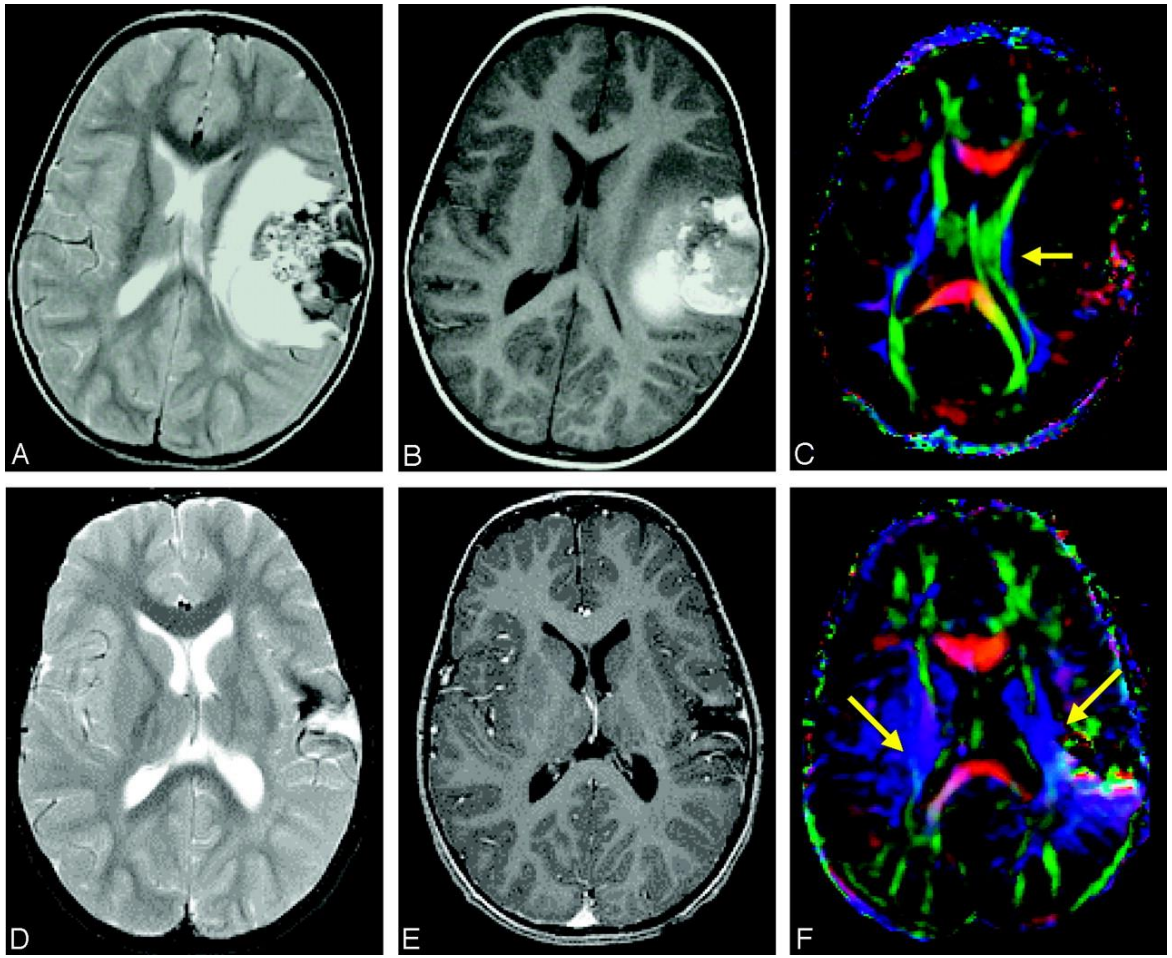
DTI Metrics

- Mean Diffusivity (MD) reflects the overall amount of diffusion
- Fractional Anisotropy (FA) represents the degree of elongation of diffusion.
- An increase of MD can accompany loss of physiological barriers to diffusion associated with cell loss or injury and is commonly observed in MS patients.
- FA is large in highly organized white matter, since diffusion is relatively elongated; tissue injury (e.g. demyelination) can therefore lead to a decrease in FA.

MR tractography



Diffusion Tensor Imaging



- MRS characterizes the chemical properties of a region of tissue, most commonly focusing on cellular metabolites

- **N-Acetylaspartate (NAA)—**MS lesions usually have lower NAA
- **Creatine—**MRS has found mixed results for Cr levels.
- **Choline (Cho)—**No significant difference between Cho concentration in isointense lesions in T1 weighted MRI and NAWM
- **Glutamate (Glu) and Glutamine (Gln)—**Elevated Glu has been reported in acute lesions and NAWM,

Functional MRI

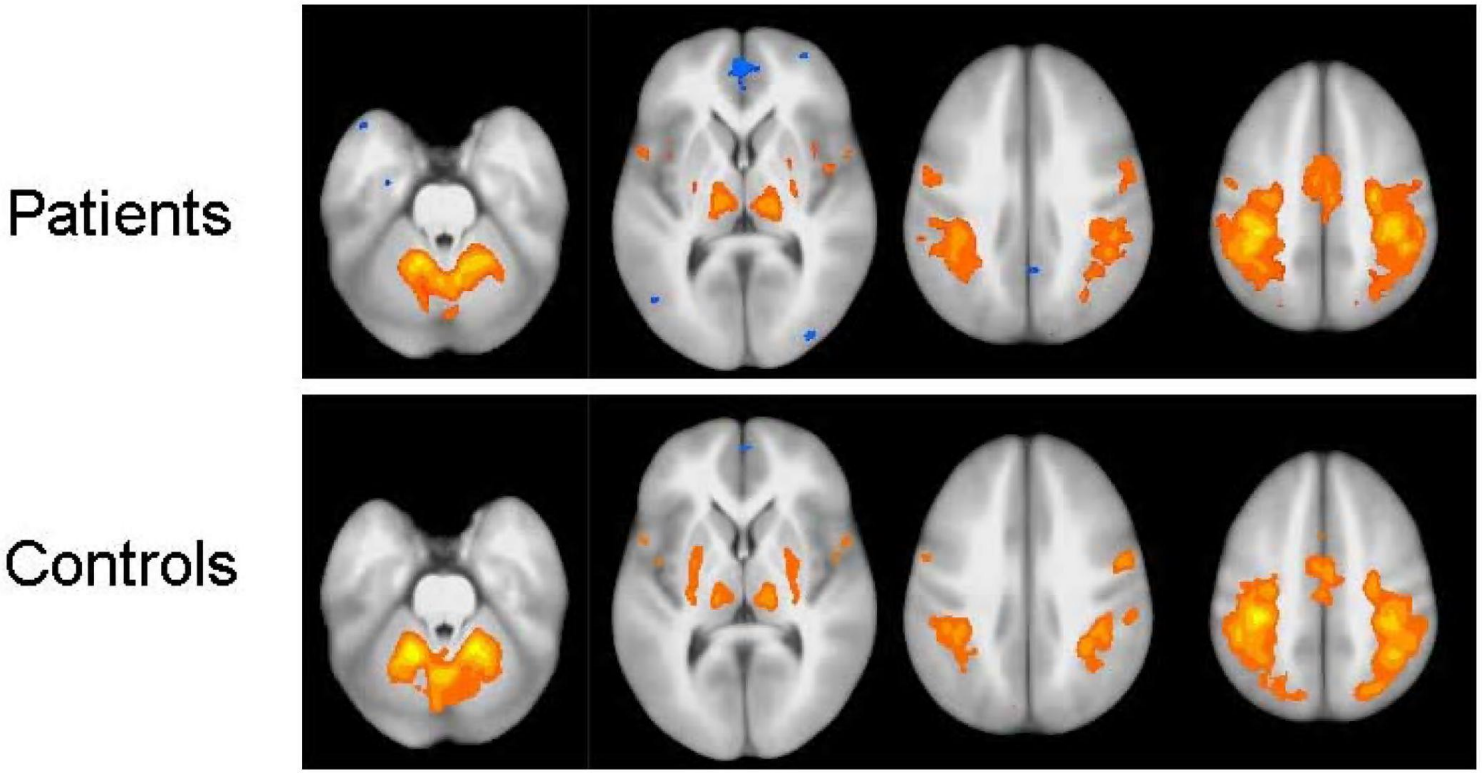


Figure 4.
Group averaged BOLD activation to a complex finger tapping task in MS patients and controls. MS patients showed 5% larger cortical volume of activation.