PET/MRI Advanced Brain Tumor Imaging

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Disclosures

- Not MRI Certified
- No Financial Disclosures
- NMTCB- Board of Directors

Agenda

Review the Diagnostic PET/MRI ABTI Protocol

- Patient population
- Routine and Advanced MRI imaging
  - General MRI acquisition overview
- MRI attenuation correction
- Metabolic imaging

PET/MRI-ABTI Purpose

- PET/MR ABTI is intended to identify the arterial perfusion, venous perfusion, capillary permeability, susceptibility, chemical composition, and the metabolism of a specified region of interest in the brain to differentiate between disease progression vs. radiation necrosis utilizing a hybrid PET/MRI scanner.

Patient Population and Criteria

- Glioblastoma Multiforme (GBM) or Astrocytoma diagnosis
- Diagnosis is unclear based on previous brain imaging, requiring more detailed diagnostic imaging data
- PET/MR ABTI secondary or tertiary imaging modality
- Exam request is approved or denied by a PET/MR committee
- Pre-screen patient for MR contraindications
- Patients must follow exam preparation instructions

Patient MRI Screening

- Screen patient for any medical implants
  - To include but not limited to pacemakers, defibrillators, cardiac stents, aneurysm clips, etc.
  - Shrapnel, metallic tattoos, or piercings
- All implants need to be verified and deemed safe for 3-T Imaging
- All patients must change into hospital scrubs
- Clothing and cosmetics may have ferrous materials
- Last step, have the patient verified using the ferrogard just before imaging

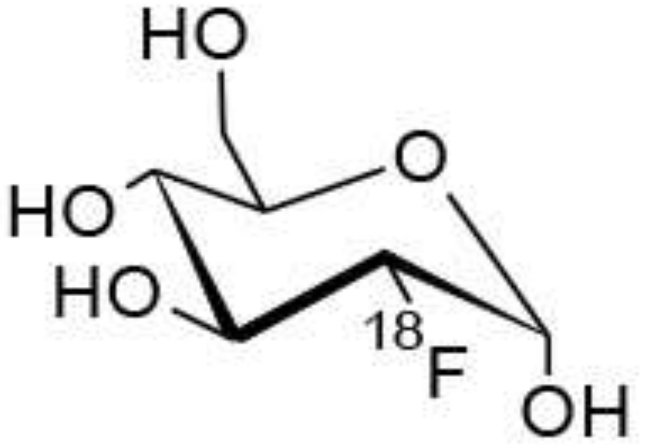
Patient Preparation

- Patients must be fasting 4 – 6 hours prior to the exam
- Diabetic patients, patients currently receiving intravenous therapy or actively taking steroids
  - BGL must be less than 250 mg/dL
- Adequate renal function eGFR ≥ 30

FDG

Radiopharmaceutical (FDG)

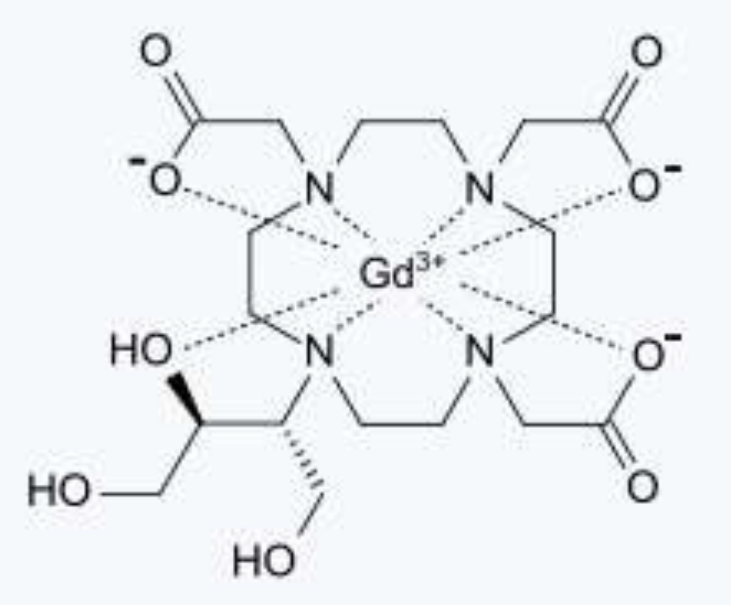
- Glucose analog used for examining biologic properties of normal vs. abnormal cellular function
- Dose range of 5 – 8 mCi intravenous bolus administration, followed by a saline flush
- Localization:
  - 1hr ± 10min
  - 5hr ± 15min



Gadavist (Gadobutrol)

MRI Intravenous Contrast (Gadavist)

- Gadolinium-based paramagnetic IV contrast
- Patients receive two IV doses of Gadavist
- Perfusion agent that can cross the Blood Brain Barrier and abnormal vascularity of the CNS
- Weight-based dosing at a concentration of 1 mmol/mL
    - Patient dose 1mL per 10kg of body weight
    - 10mmol is the max amount that can be given at a time



Dedicated PET/MR (GE SIGNA 3 Tesla)

- High-quality anatomical resolution and soft tissue contrast
- Eliminates 50% to 70% of radiation exposure
- Hybrid PET/MR scanners have a smaller bore (60cm)
- PET/MR exams take longer than PET/CT exams of the same body area
- PET bed and some MRI sequences acquired simultaneously

Patient Management

- Post-FDG administration
- Initial and delayed brain imaging:
  - 1hr ± 10min
  - 5hr ± 15min
- Need to allocate more time to set up the patient for the PET/MR vs PET/CT
- May need to begin patient set up 15-20min before anticipated PET acquisition but is patient dependent
- Patient safety and comfort are key
  - Claustrophobic patients, patients with a 3T safe implant
- MRI Coil selection is crucial to optimal image quality

MRI Coil Selection and Patient Positioning

- Low MRI signal requires the use of anatomically specific extrinsic coils for signal enhancement
- PET/MR – ABTI utilized an 8-Channel brain coil
- No patient motion, suggested using moldable foam wedges to minimize motion

PET/CT – Attenuation Correction (AC)

- PET/CT (AC) – CT based on tissue density that is represented in Hounsfield Units (HU)
- Dense structures such as bone have a high HU of (+1,000)
- Air has a negative HU of (-1,000)
- Water has an HU of (0)
- Using the average CT kilovoltage and CT attenuation coefficients based of different tissue types are mapped to the 511 keV of the annihilation photon
- Allows for CT based attenuation correction

- Magnetic Resonance based attenuation correction is a bit different

PET/MR – Attenuation Correction (MRAC)

- MRI acquisitions – variations in proton relaxation times are used to acquire diagnostic images
- No correlation between tissue density attenuation coefficient and MR signal intensity
- MRAC Challenges:
  - Bone is dense but has low proton signal in MRI which is the opposite for CT based attenuation correction where bone is dense
  - MRI coils used for imaging are made of dense materials and attenuate annihilation photons
- Manufactures have developed two MRAC options

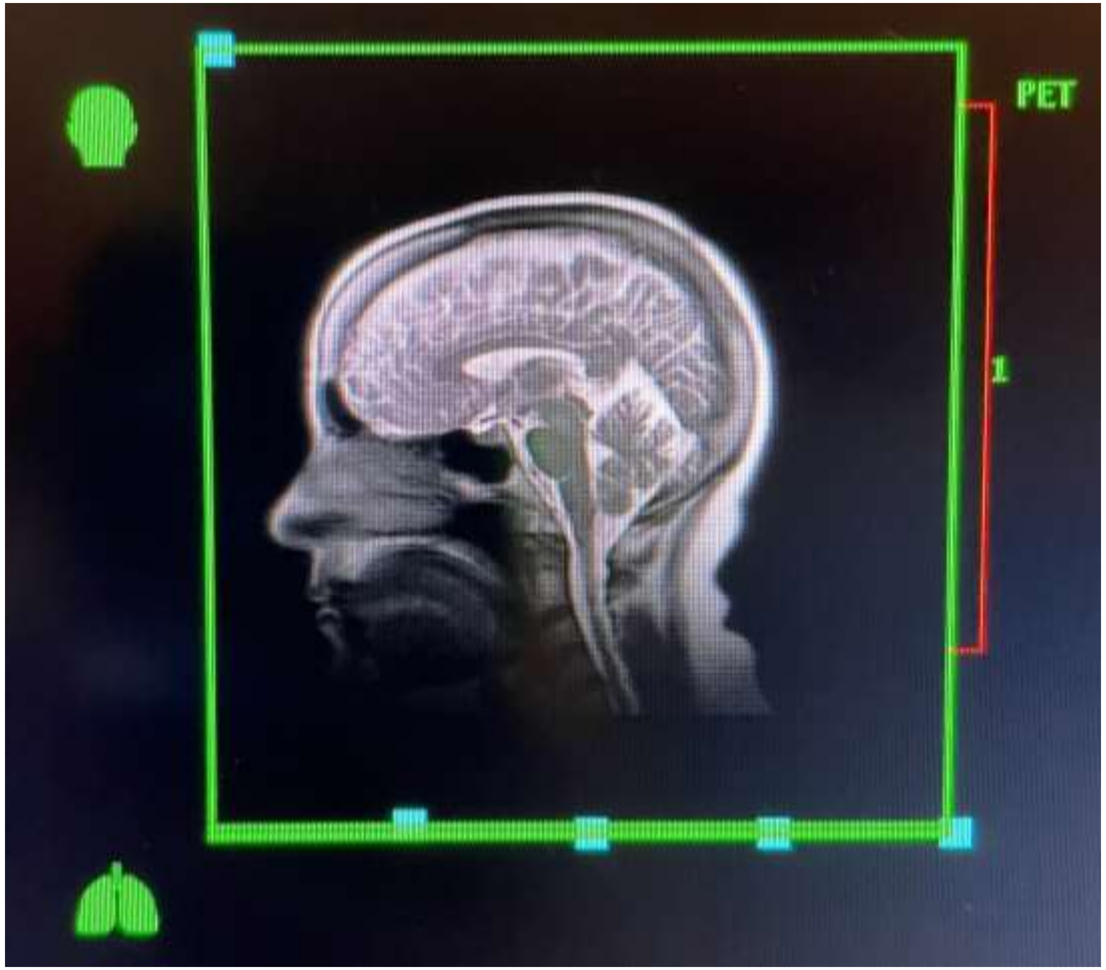
PET/MR – Attenuation Correction (MRAC)

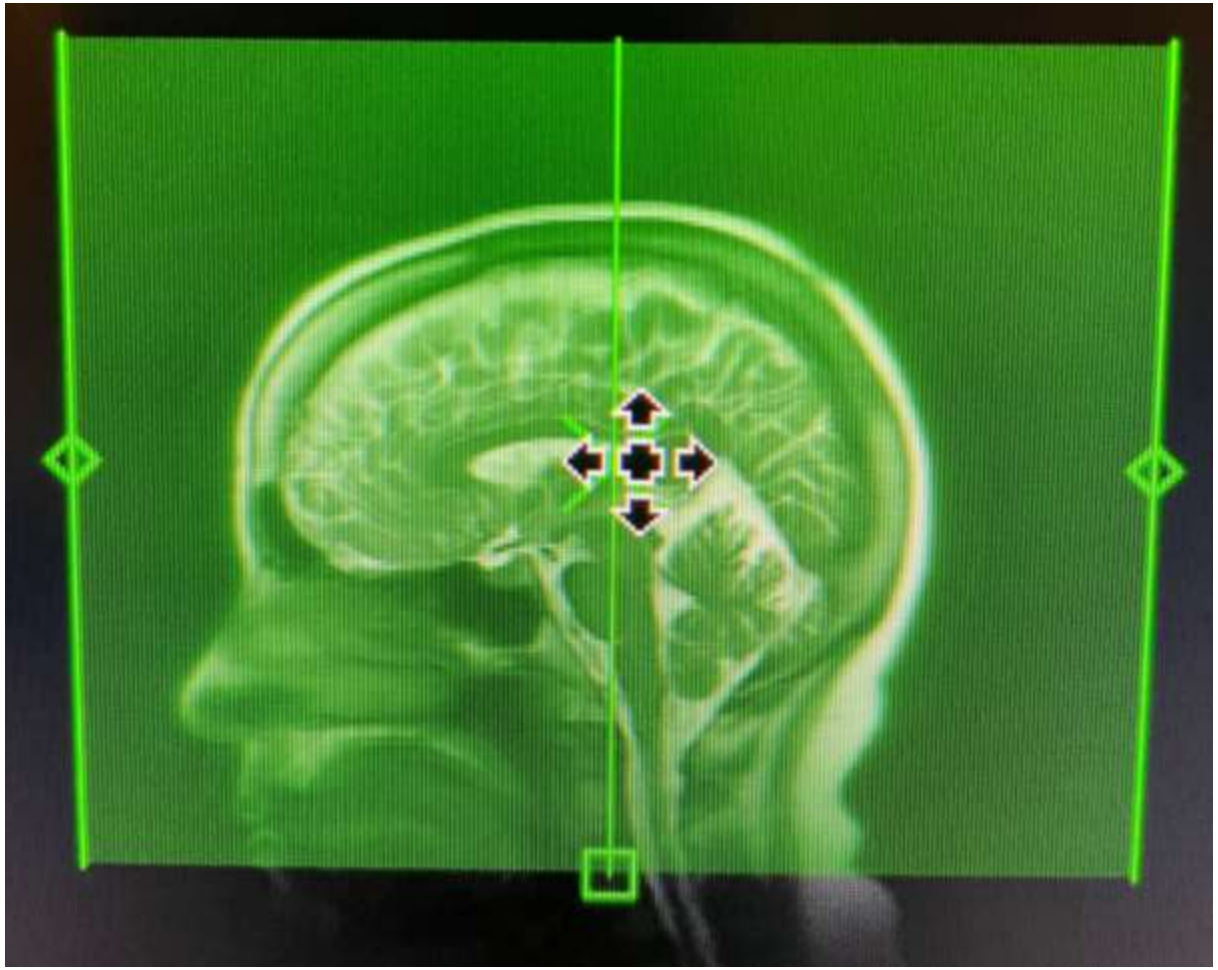
- Head Imaging:
  - MRI Based: ZTE (Zero Echo Time)
    - Pulse seq utilized for musculoskeletal imaging
  - CT- Based:
    - Population CT based Anatomy Atlas
- Body Imaging:
  - Dixon Technique MRI pulse sequence
  - (water/fat separation and conversion to HU values at 511 KeV)
  - Ideal for soft tissue imaging

PET/MR – Attenuation Correction (MRAC)

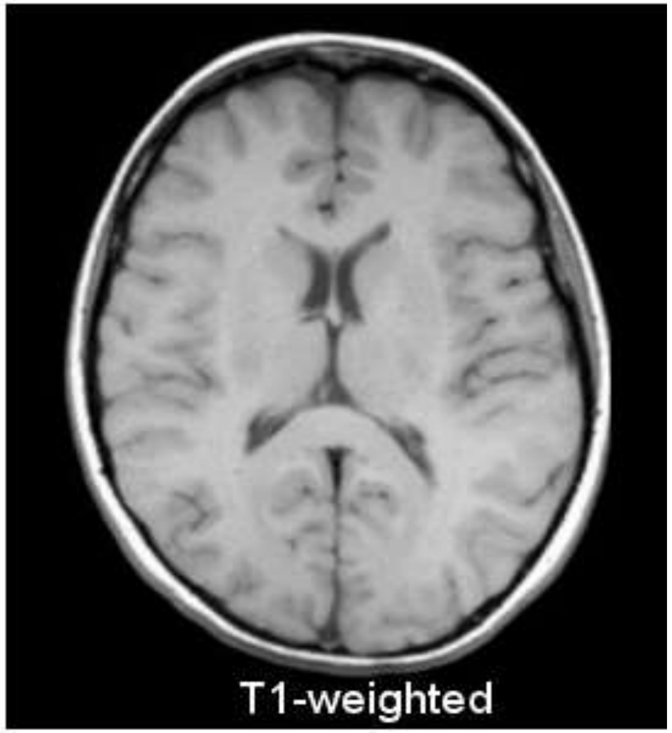
- MRI coils are used to enhance the signal from proton relaxations
- For PET/MR - most brain and body coils have a measured attenuation coefficient
- Some coil attachments do not have a measured AC coefficient
- Need to be aware of AC coefficients for coils and their attachments

PET Bed - Brain

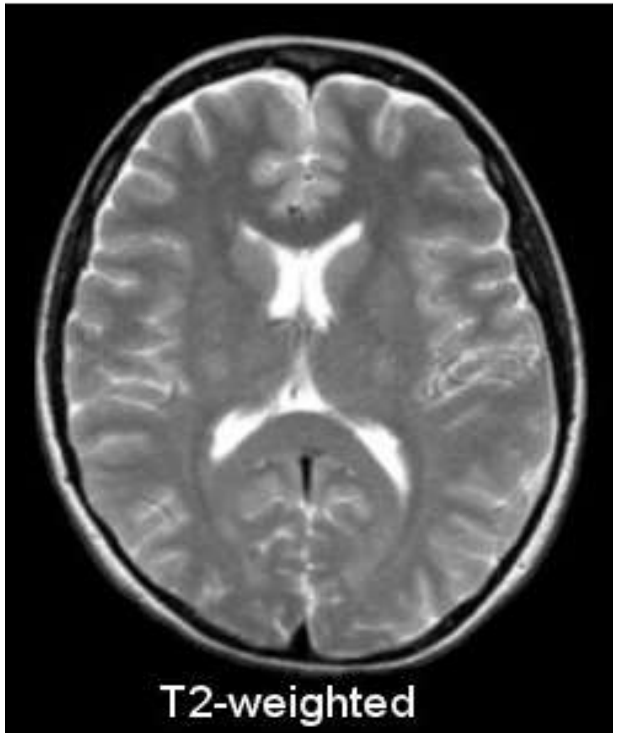




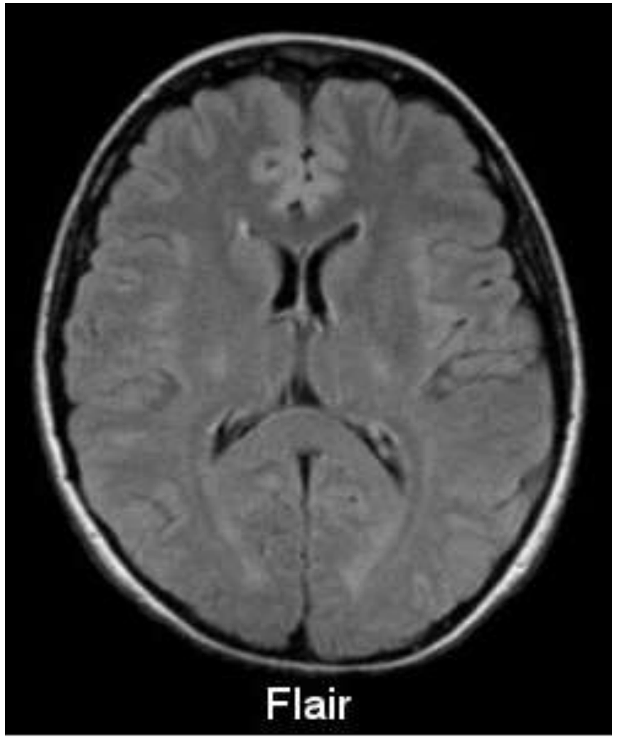
MRI – Routine Sequences



CSF appears dark



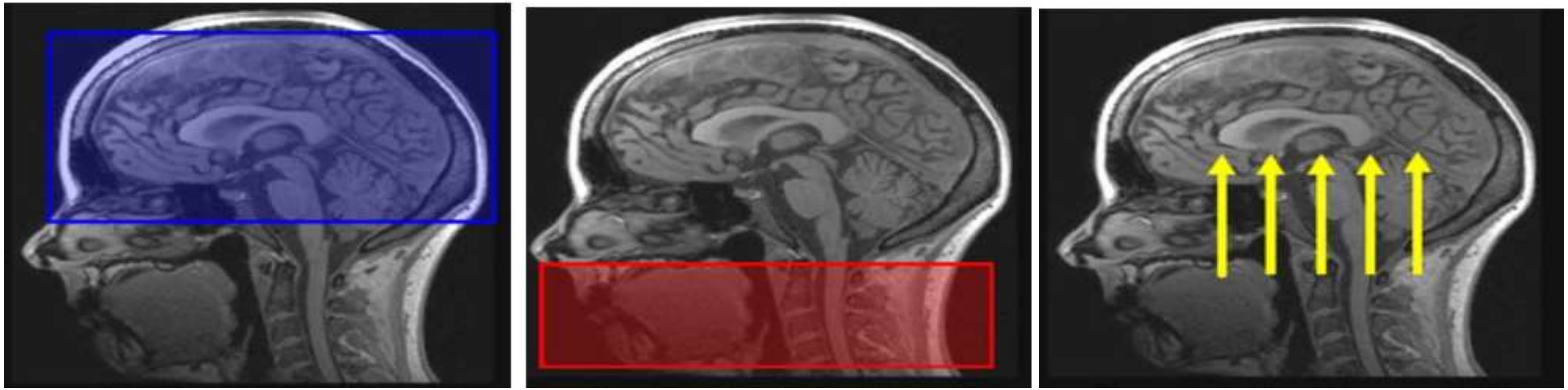
CSF is bright



Abnormalities are bright while CSF is suppressed

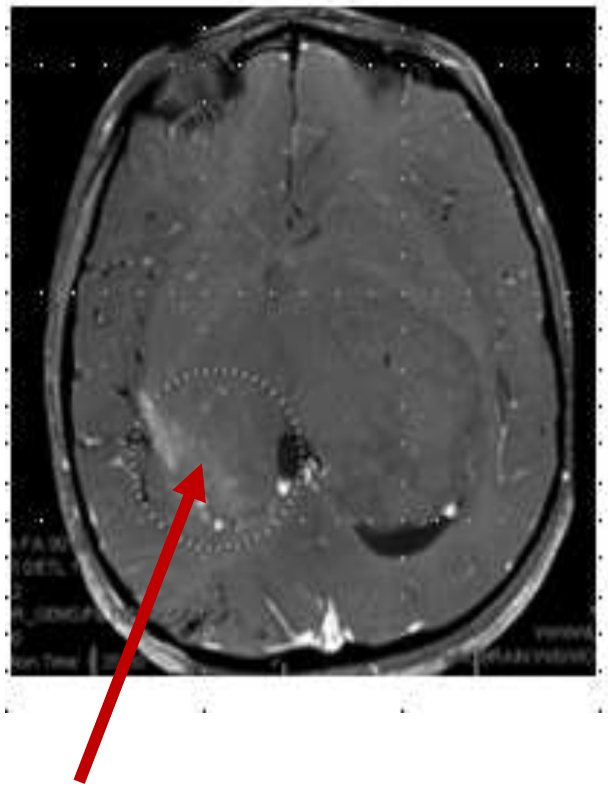
MRI - Arterial Spin Labeling Acquisition

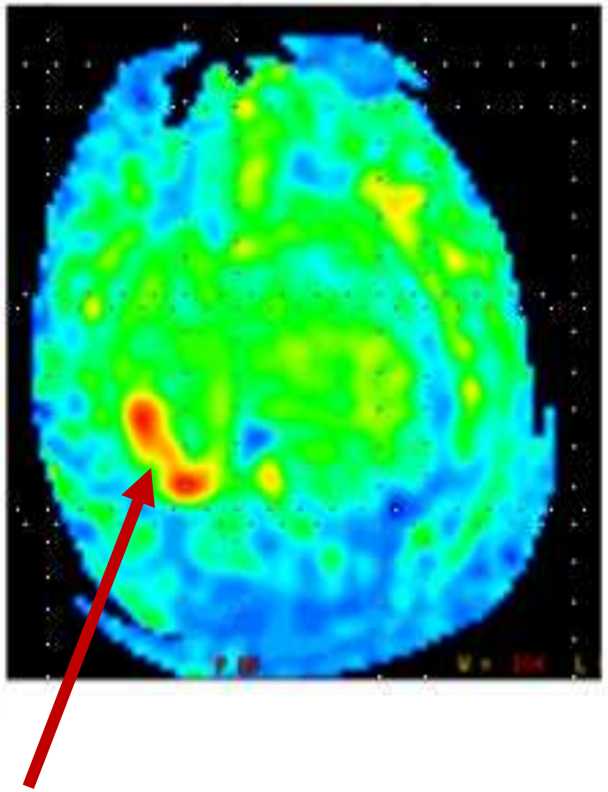
- Non-contrast sequence
- Magnetically labels arterial blood water protons
- Aids in identifying and quantifying areas of increased arterial perfusion



MRI - Arterial Spin Labeling

- Right posterior hemisphere region of interest
- Cerebral blood volume mapping is above the background
- Increased arterial perfusion in ROI
- May be indicative of disease progression





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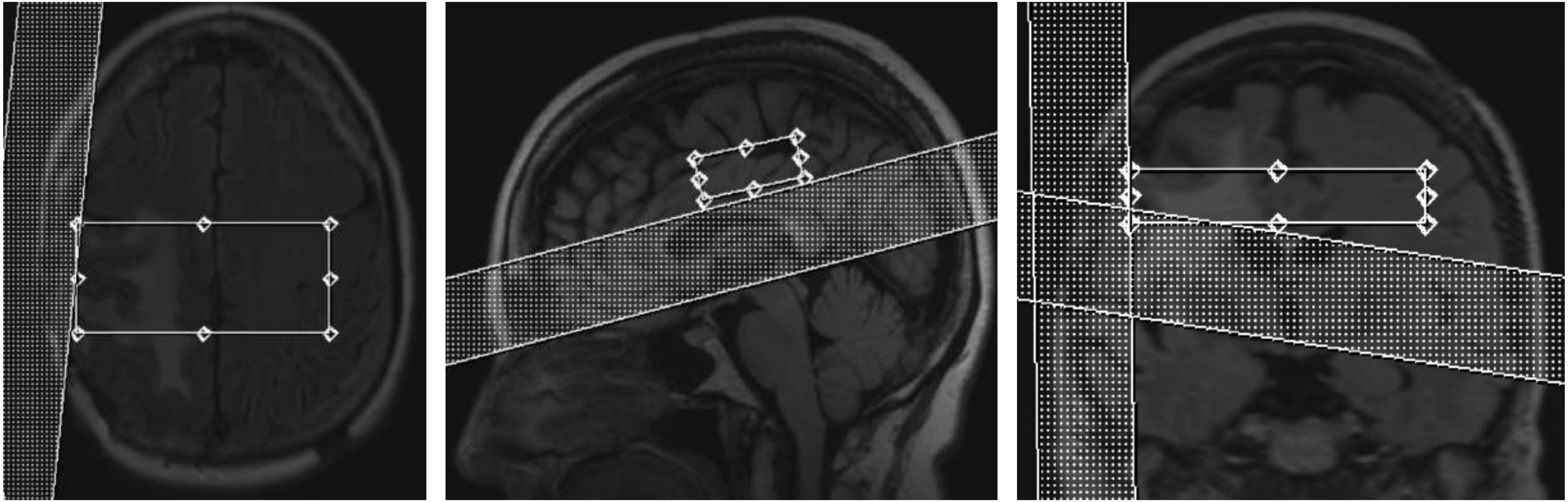
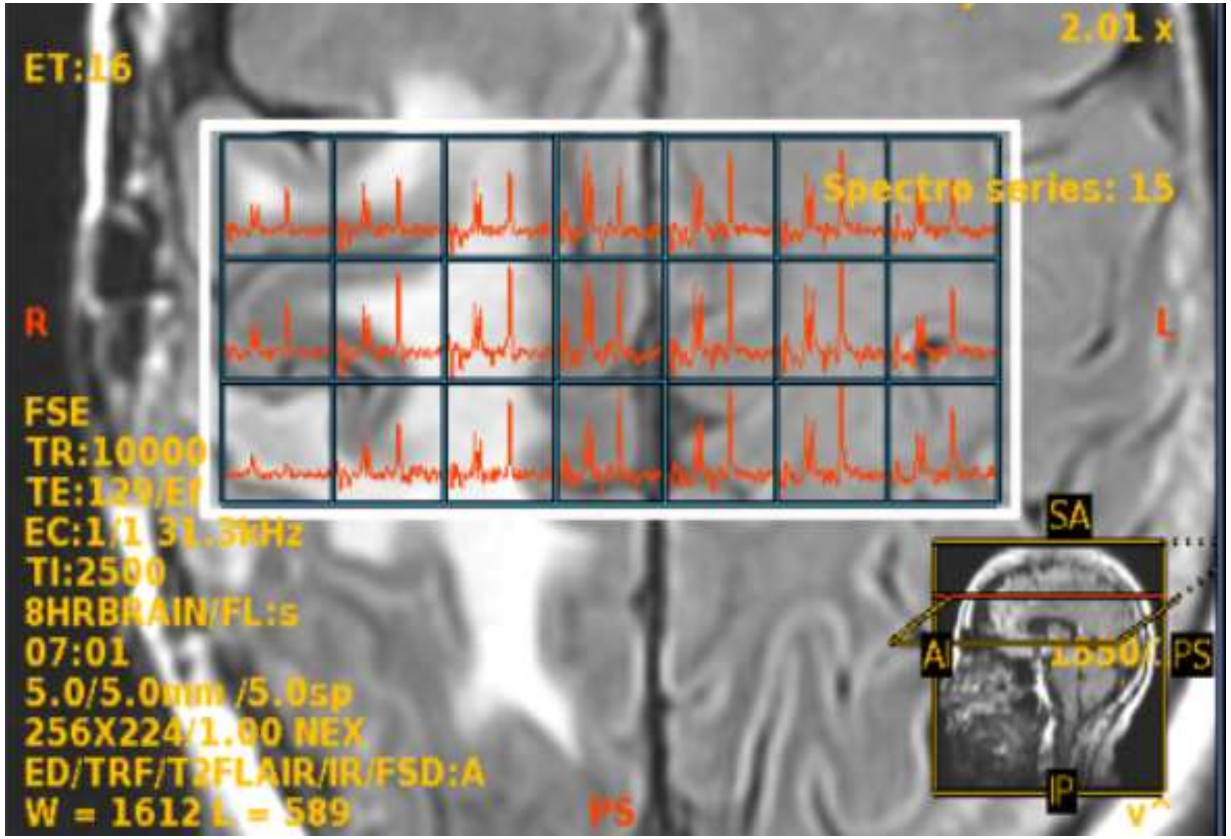
MRI – Spectroscopy

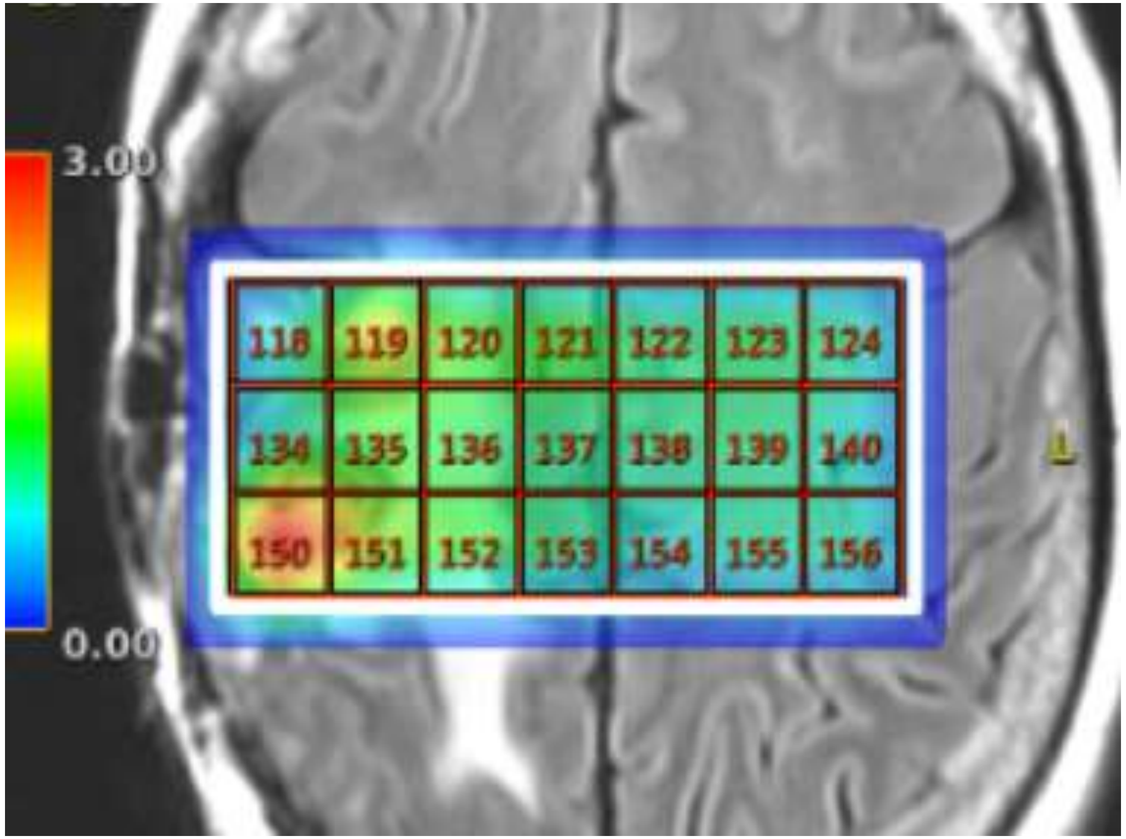
- Non-Contrasted acquisition, **VERY** sensitive to intrinsic metabolites
- Measures the chemical composition of a specified brain region
- Chemical shift characterization of metabolites in millimolar concentrations (mM)
- Single-voxel or multi-voxel over a region of interest
    - Acquire a non-diseased area and a diseased area for comparison
- Choline to Creatine ratio helps to identify mid-grade to high-grade tumors
- Bone and CSF motion will affect the spectroscopy measurement
    - Saturation Bands

MRI – Spectroscopy SAT Bands



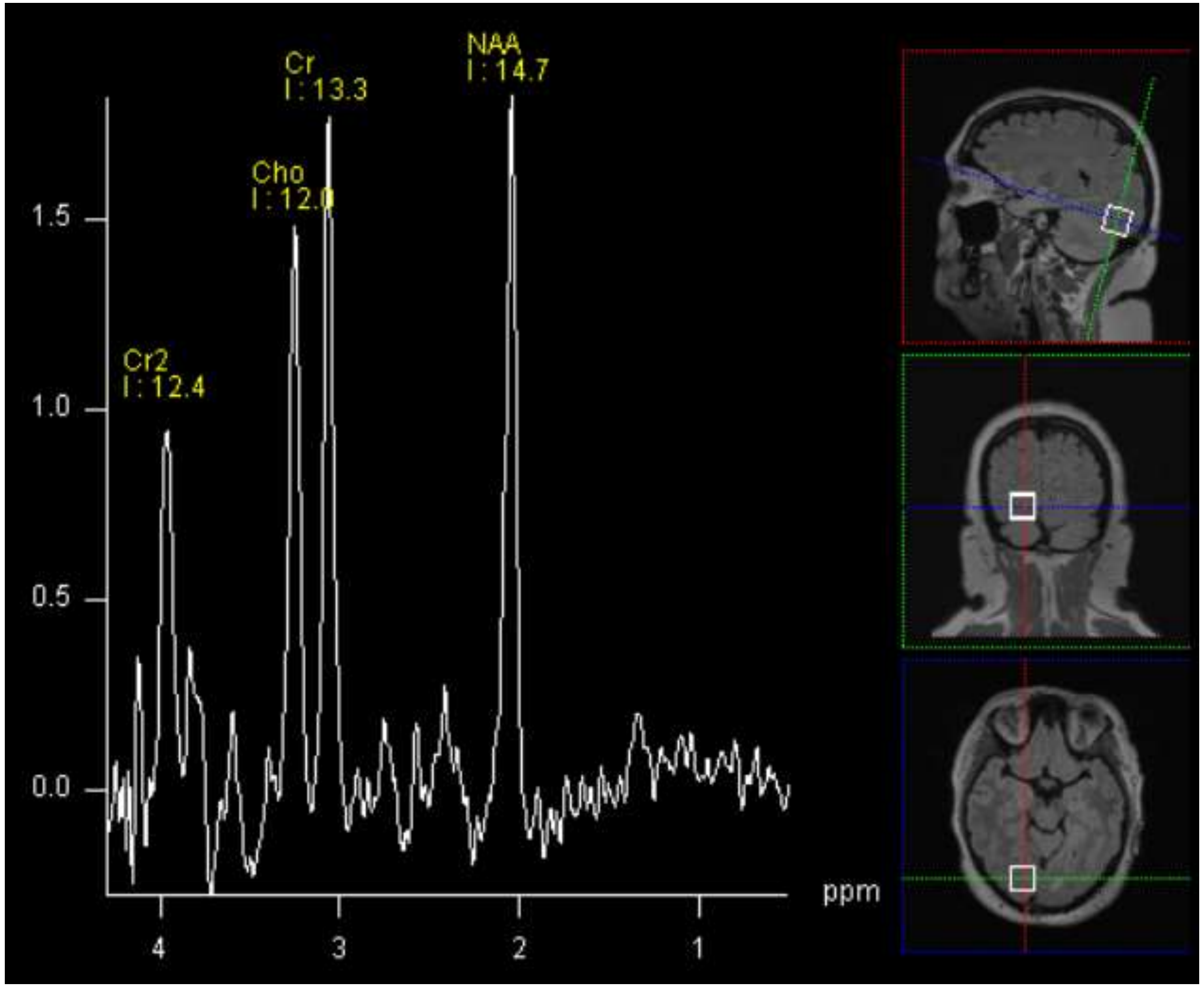
MRI – Spectroscopy Multi-Voxel





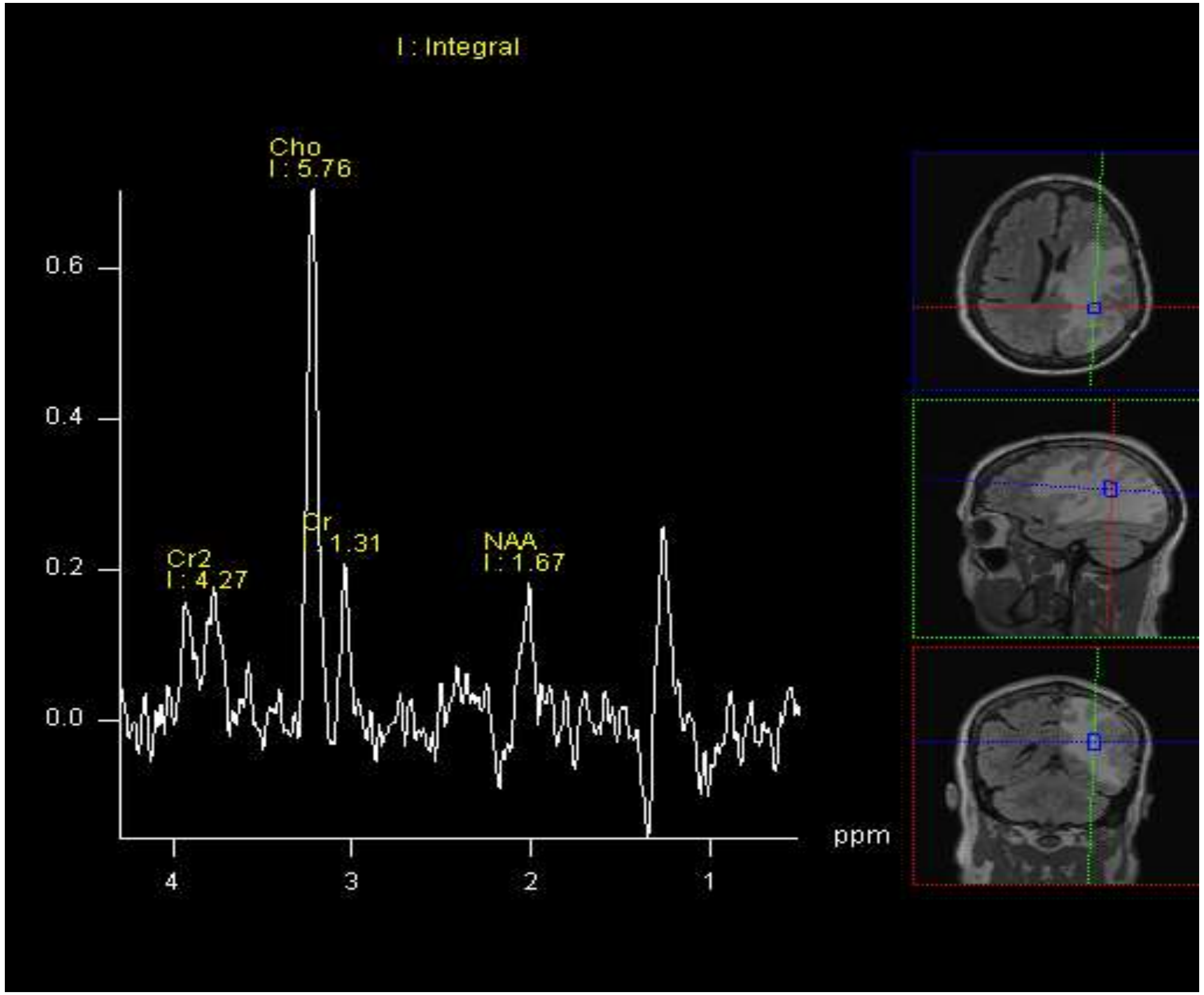
MRI – Spectroscopy Single Voxel

- Chemical shift characterization of metabolites in millimolar concentrations (mM)
- Focusing on:
  - N-Acetyl aspartate (NAA)
  - Creatine (Cr)
  - Choline (Cho)



MRI – Spectroscopy Abnormal Single Voxel

- Abnormal metabolite shift
- Elevated Choline/Creatine ratio of 5:1
- Most likely consistent with high-grade tumor



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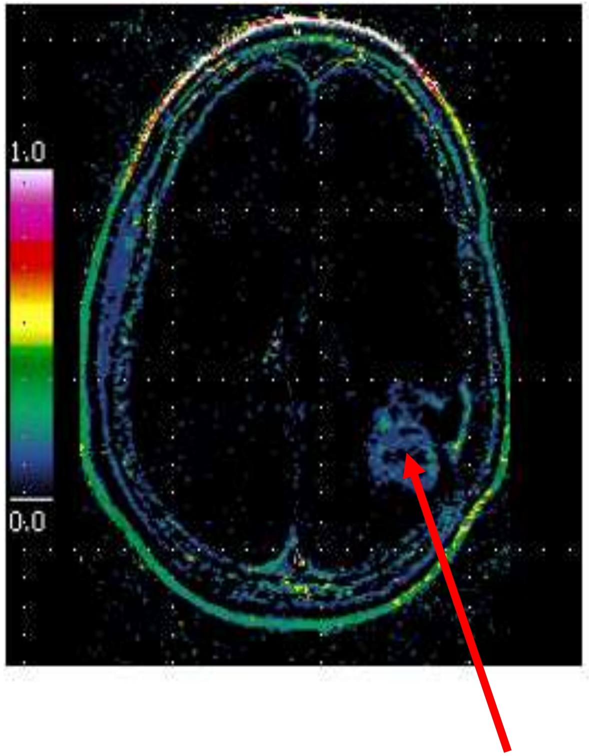
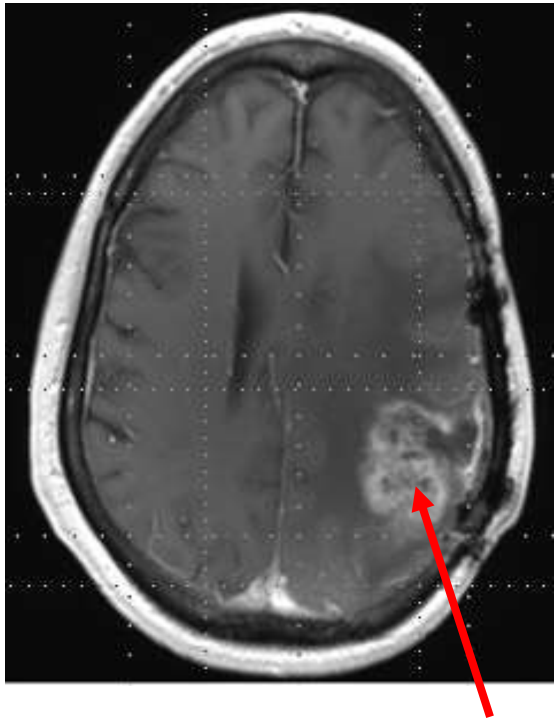
MRI – Dynamic Contrast Enhanced (DCE)

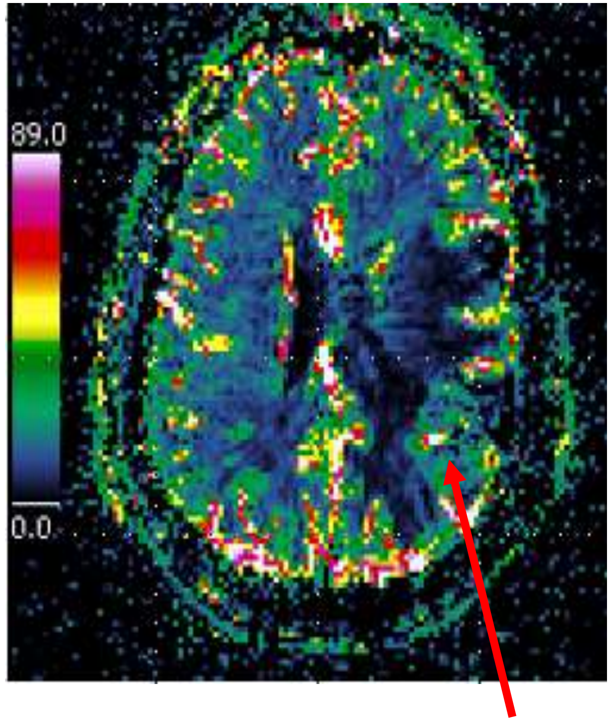
- Gadavist-enhanced venous perfusion acquisition
- Dynamic images used to form a k^{trans} map, a measure of capillary permeability
- Volume transfer of gadolinium between blood plasma and the extravascular extracellular tissue



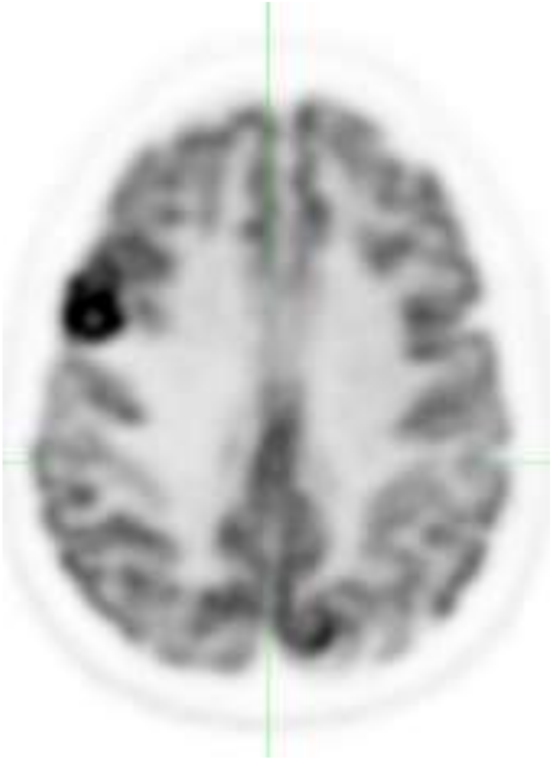
MRI – Dynamic Susceptibility Contrast (DSC)

- Second dynamic Gadavist intravenous administration
- Evaluating cerebral blood volume
- Aids in identifying angiogenesis of capillary flow arising from excising blood vessels
- Microvascular quantification may provide insight into neoplastic brain lesions

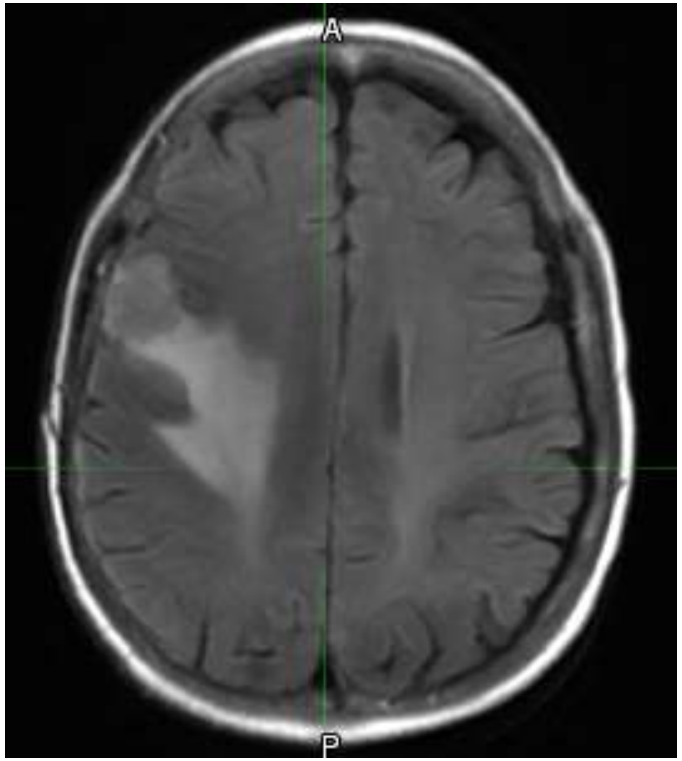




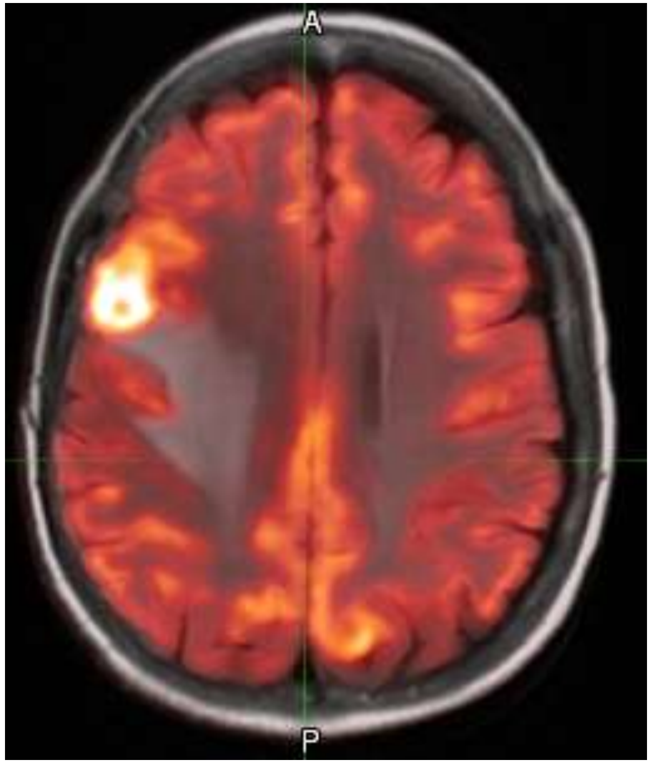
PET Metabolic Imaging



ROI - Right frontal Lesion
1hr Max SUV = 19.1

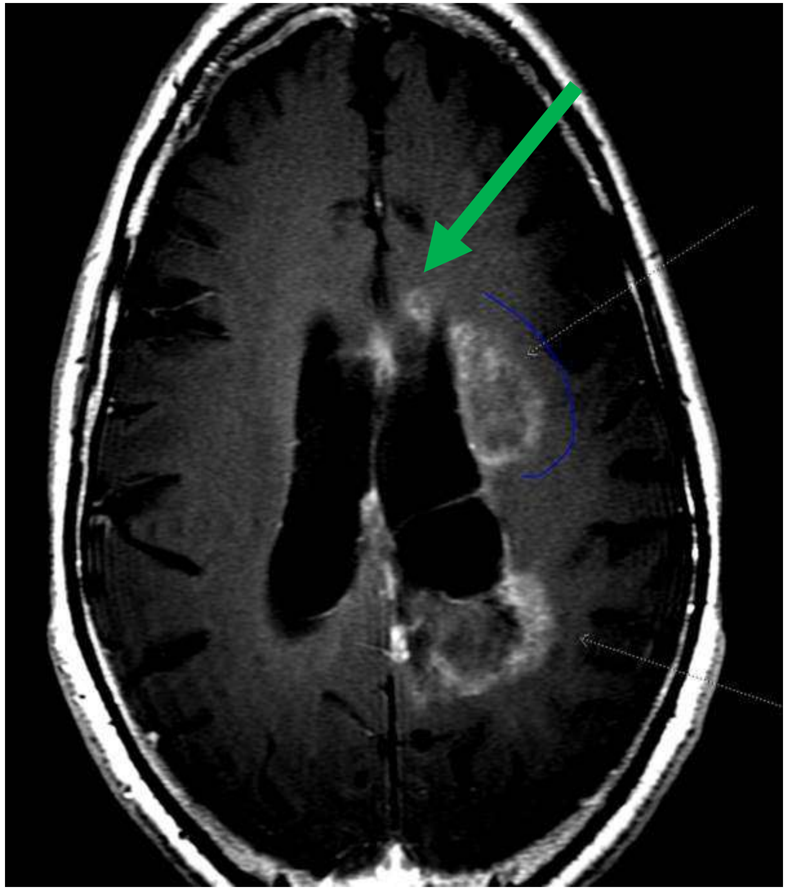


Gadolinium Enhanced Perfusion

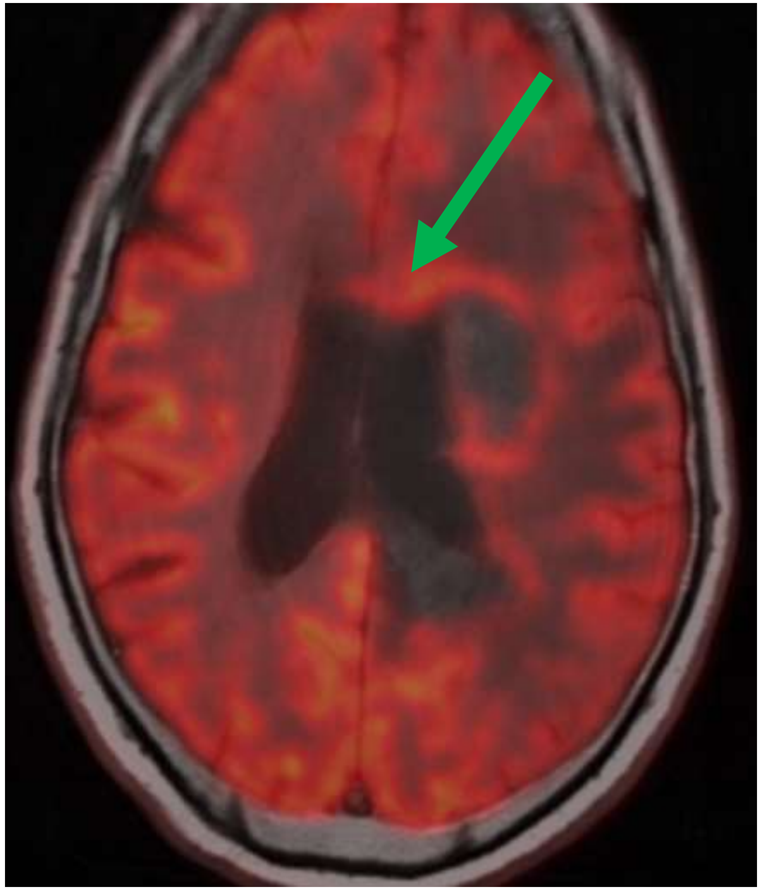


Fused PET MRAC to Ax Flair

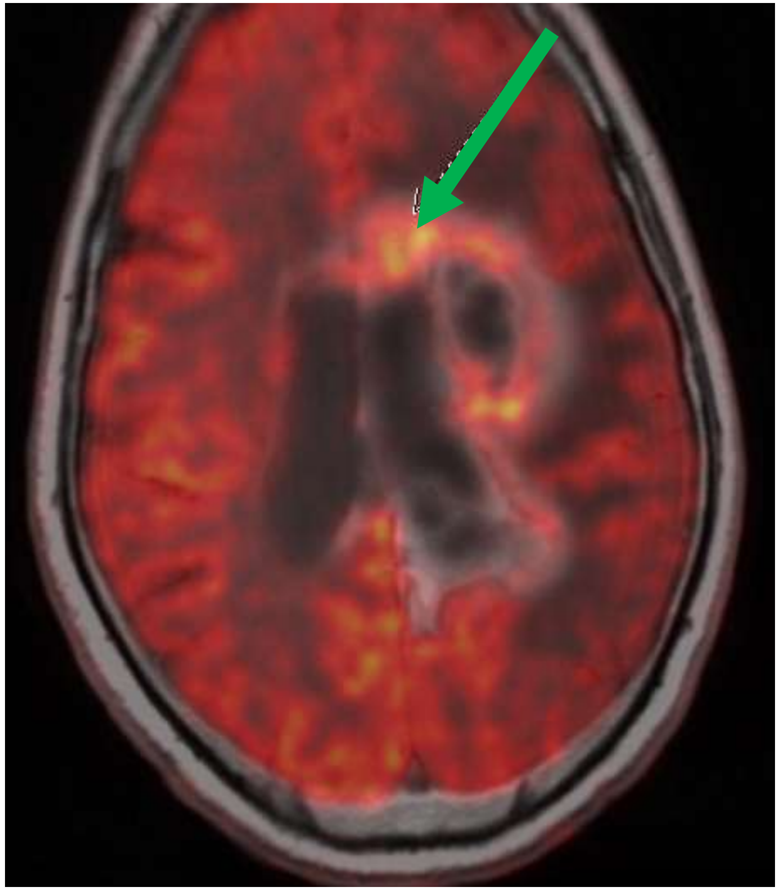
PET Metabolic Imaging



ROI - Right frontal cortex



1hr image SUV = 12



5hr image SUV = 16.9, post contrast

Review of PET/MR - ABTI Images

- Radiologist will compare:
  - Arterial Spin Labeled Image
  - Spectroscopy
  - Dynamic Contrasted Enhanced Image
  - Dynamic Susceptibility Enhanced Image
  - Metabolic FDG PET Image
- All five acquisitions aid in determining disease progression vs. radiation necrosis

Conclusion

- The complex MRI sequences require longer imaging sessions but result in excellent soft tissue visualization.

- FDG PET 1hr and 5hr acquisitions add complementary metabolic data.

- PET/MR ABTI is a complex diagnostic protocol aiding radiologists with difficult cases to differentiate disease progression vs radiation necroses.

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