Brain & Spinal Cord MRI Scans with New Techniques Offered at the Detroit Medical Center Multiple Sclerosis Center MRI Facility

All MS patients who are imaged at the DMC MRI Facility undergo additional image analysis that is not performed anywhere else in Michigan.
Multiple Sclerosis MRI Facility

- The MS Center Imaging Laboratory is affiliated with the Detroit Medical Center (DMC) MRI Facility

- The downtown MRI Facility has five state of the art MRI scanners

- The suburban Rose Imaging Facility of the DMC has one state of the art MRI scanner in Southfield/Farmington Hills area.

- MRI scanners are graded by their magnet field strength.

- MRI scanner strength is measured in Tesla units or simply referred to as “T”

- Our MRI facility includes one 1.0T, three 1.5T, one 3.0T, and one 4.0T scanner

- This is the only facility in Michigan with a 4.0T human MRI scanner
An Introduction to MRI Scanning in Multiple Sclerosis Offered at the DMC & WSU MS Center Image Analysis Laboratory
T2W Lesions

• T2 weighted (T2W) images are highly sensitive to water (proton) based signals

• Abnormal fluid (water) in the brain or spinal cord tissue is seen as a “white spot” or T2 hyperintense lesion

• The T2W hyperintense lesion is a fundamental part of the McDonald MRI diagnostic scheme

• Typical lesions for MS are usually ovoid in shape, periventricular in location, greater than 5 mm in diameter, with a propensity for the corpus callosum, and some lesions radiating perpendicularly from the ventricles and corpus callosum known as Dawson’s lesions
Classic T2W Lesions in Multiple Sclerosis
T1 Weighted Lesions
T1W Lesions (Black Holes)

• In contrast to T2W images, T1W images produce “hypointense” or darker appearing lesions

• The hyopintensity (or the darkness) of the T1W lesion has led to the commonly used term T1 black holes or simply “black holes”

• A T1W lesion can be enhancing (acute) or non-enhancing (chronic)

• An acute T1W enhancing lesion can resolve entirely without leaving behind any tell tale signs and become just like normal appearing tissue in the brain or become “isointense”
T1W Black Holes and Tissue Pathology

Permanent T1W are the best markers of irreversible tissue loss in MS on conventional MRI

The vast majority of new lesions appear as new gadolinium enhancing lesions on T1W images with concurrent hyperintense lesions seen on T2W images.

Of these, almost 70 to 80% of lesions resolve spontaneously over the following 6 to 12 months.

These T1W lesions with enhancement represent acute inflammation and edema that usually resolve spontaneously over time.

In fact, several months later most of the areas where enhancement was initially seen become isointense.
Tracking the Evolution of a New Lesion
Tracking the Evolution of a New Lesion

- The remaining 20 to 30% of lesions become T1W “black holes” and represent irreversible tissue loss. They are visualized as T1W black holes and do not resolve
MS Lesion Evolution into Black Holes

**Case 1**
New enhancing lesion resolving over time

**Case 2**
New enhancing lesion evolving into a permanent T1W black hole
Detecting Brain Tissue Loss or Brain Atrophy
In healthy state, brain volume decreases by app 0.2% per year. In MS, brain volume decreases by approximately 0.8 to 1.0% per year…..almost 4 to 5 times faster!
Emerging MRI Techniques to Measure Brain Tissue Injury in Multiple Sclerosis

Atrophy MTR 1H-MRS Tractography Quantitative cord imaging

fMRI DTI OCT

1H-MRS Tractography Quantitative cord imaging SWI
Brain Magnetization Transfer Ratio
or MTR Imaging:
A Relatively Myelin Specific Imaging Technique
Brain MTR in MS

• Healthy adults and most RRMS have brain MTR values between 45% and 50%

• A new acute enhancing lesion may have an MTR as low as 20% which may recover to normal or near values as inflammation and edema resolve. In other words, this may be reversible

• A chronic T1W black hole may have an MTR value as low as 20% that is unlikely to change because of irreversible myelin and axonal loss

• Post-mortem studies have demonstrated that myelin content in the brain correlates with MTR i.e the higher the MTR the higher the myelin content

• Therefore, long-term prospective studies examining brain MTR may indicate to some degree remyelination and repair

• Brain and cervical cord MTR have shown both predictive value and high degree of correlation with clinical disability
Brain Magnetization Transfer Ratio in MS

MTR = 40%-50% in normal appearing tissue

MTR = 37% in a mildly hypointense area

MTR = 21% in a chronic black hole representing demyelination and axonal loss
Magnetic Resonance Spectroscopy or MRS: An Imaging Technique to Measure Neuronal/Axonal Function
Brain MRS is a highly sensitive imaging tool to study tissue injury and function at the cellular level.

MRS is based on suppressing water based signal (protons) and enhancing chemical metabolite signals through complex MRI software applications.

The result is the generation of a chemical spectrum that depicts underlying molecules detected in the spectrum.

MRS is usually done either in a large area of the brain central white matter referred to as a multi-voxel technique (app 40 to 120 ml) or a small area of brain approximately 1 to 2 ml (single voxel).

MRS is highly sensitive to image acquisition technique and requires experienced technicians and physicists performing MRS.
• The most commonly studied metabolite in MS is N-acetyl aspartate or NAA

• NAA is exclusively produced by the mitochondria in the neurons in the CNS. Therefore, NAA is thought to be a reliable marker of neuronal viability

• Other metabolites that can be measured include glutamate, myoinositol, lactate, lipids, choline, and creatine

• NAA is usually expressed as a ratio to creatine (NAA:Cr) or in absolute values in millimoles (mmol). Both techniques have their limitations but lately, there has been an attempt to quantify NAA levels in mmol rather than a ratio to creatine

• NAA levels in an acute new enhancing lesion can be reversible whereas it remains low in chronic black holes

• Over all, brain NAA levels decline over time in patients with RRMS

• Therefore, maintaining or restoration of NAA levels over a long-term period may indicate neuronal metabolic recovery or to some extent, a form of neuroprotection
An Example of Brain MRS Scan
Diffusion Tensor Imaging or DTI
DTI Applications

- Demyelinating disorders, White matter maturation
- Neonatal brain & cord development
- Early detection of stroke
- Monitoring *in vivo* temperature changes with therapy
- Relative axonal density (neuronal density)
- Detection of ischemic tissue ~ mn after onset of stroke
- Neurodegenerative processes: Alzheimer, PD
- Tuberous Sclerosis
- **Multiple Sclerosis**
Diffusion Tensor Imaging

- DTI is based on the principle of measuring water molecule motion in the CNS.

- Typically water molecule motion occurs in an organized manner with limited random or haphazard motion. This phenomenon is known as water diffusion which in a normal or healthy tissue is rather limited i.e. diffusion is low. This is also referred to as diffusivity.

- Water molecules also tend to move along the longitudinal direction of nerve fibers in a healthy tissue. This directional movement of water molecules is known as anisotropy, sometimes referred to as fractional anisotropy.

- In an MS lesion as well as the so-called normal appearing tissue, diffusivity is increased. Similarly, in an injured tissue such as MS lesion, anisotropy is decreased because water motion is more haphazard and not directed along the longitudinal direction of nerve fibers.

- In a new acute enhancing lesion, DTI changes can be reversible.
**Diffusion Tensor Imaging (DTI)**

- **PD-weighted image**
- **Post-contrast T1-w image**
- **Mean Diffusivity map**
- **Fractional anisotropy map**

**Cercignani et al., JNNP 2001**

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<th>Controls</th>
<th>MS</th>
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<tr>
<td>Mean NAGM D</td>
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<tr>
<td>Mean NAGM MTR</td>
<td>39.8</td>
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**Guevara et al., Arch Neurol 2004**

- **Mean NAGM MTR**
  - p = 0.005
- **Mean NAGM MD**
  - p = 0.0014

**Months**
Functional MRI or fMRI
Functional MRI (fMRI)

- Functional MRI or fMRI is an MRI technique that is based on detecting changes in regional blood flow in the brain.
- These changes are dependent on the tasks being performed by the subject. For example, moving a hand or recalling names will increase blood flow in the respective areas of the brain.
- fMRI also helps to define abnormal patterns of brain activation that arise from disease.
- It is used in MS to assess brain neuronal activation required to perform simple motor or memory tasks.
- In RRMS patients, a bigger area of the brain is activated to perform simple tasks as compared to healthy controls.
- This is also referred to as CNS plasticity i.e. the ability of the brain to adapt to injury and maintain its functional ability.
- However, over time as the disease progresses, the brain tends to lose its plasticity as well as its functional capability.
fMRI: Color Flow Changes in MS Patients and Healthy Controls

RRMS

MS patients activating large areas of the brain cortex while performing memory recall tasks

Controls

Healthy controls performing the same tasks with a much smaller area of cortical activation
## Summary of New MRI Techniques in MS

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<th>Imaging Technique</th>
<th>Outcome in MS compared to Healthy Controls</th>
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