Why Focus on MR in the CNS?

Non-invasive biologic endpoint.
- Related to metabolism, perfusion.
- Routine at many sites.
- Quantitative.
- Correlates with patient status.
- Rapid measure of early lesion volume.
  - Patient selection, measure of baseline.
- Reduce sample sizes needed.
- Becoming accepted surrogate endpoint.

Why Focus on MRI?

- Screen for ischemia
- Screen for bleeds
- Patterns in acute stroke
- Relevant lesions, histology
- Metabolic diseases
  - CJD, pediatric disease
  - DWI-perfusion “mismatch”
- “Tissue at risk”
- DTI for connectivity (FA)
- FA in cognition
- fMRI correlates
  - “Fiber-tracking”

Why do ADCs of water decrease in acute stroke?

- perfusion deficit
- energy deficit
- failure of Na+/K+ pumps
- intracellular imbalance of K+/Na+
- influx of water
- Eventual lysis/edema
- DWI hyperintensity
- Mobility hindered = ADC drop
- glial and neuronal swelling
  - reduction in extracellular space

EPI is Ideal for DWI

- 90° rf
- 180° rf
- EPI Readout
- G
- T2-wt (D=0)
- DWI (D=200)
- ADC map
DWI FLAIR-EPI Protocol

1. Inversion RF
2. EPI Readout
3. X, Y, Z
4. X, Y, Z
5. T2-wt
6. FLAIR (b=0)
7. DWI (b=800)
8. ADC
9. FLAIR-ADC

Results – Images and Summary

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>FLIPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b=0</td>
<td>b=1000</td>
</tr>
<tr>
<td>Normal Mean*</td>
<td>1.10</td>
<td>0.84</td>
</tr>
<tr>
<td>Normal SD*</td>
<td>0.43</td>
<td>0.19</td>
</tr>
<tr>
<td>Lesion Mean*</td>
<td>0.71</td>
<td>0.80</td>
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<tr>
<td>Lesion SD*</td>
<td>0.26</td>
<td>0.18</td>
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</tbody>
</table>

Mean and SD of FLIPD-ADC significantly differ from Conventional-ADC, p < 0.001

Latour, Warach, et al NIH

The Elements of DWI: The Protocol

Acquire gradient axes X, Y, Z – also B0!
Averaged as “trace” or “average” ADC, DWI.
If time, then: FLAIR ADC, DTI, PWI.

ADC (b=0)

T2-wt

Mean and SD of FLIPD-ADC significantly differ from Conventional-ADC, p < 0.001

Latour, Warach, et al NIH

ADC vs T2-wt Hyperintensity

Time After Onset of Stroke (h)

ADC

T2-wt SI

NOTE: DWI images are also T2-wt. T2-wt hyperintensity adds to DWI. If bright on b=0, likely bright on b1000. Only the ADC sorts this out.
DWI for Routine Stroke Workup

DWI alters the neurological assessment in ~ 40% of cases.

**History**
70 yo man with right-sided weakness

**Clinical impression**
left-anterior, subcort-<1.5 cm infarct

**MRI at 20 hrs**
T2 - lesion A only seen DWI - embolic pattern

**Consequence**
TEE - PFO, aortic plaque

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DWI as Potential Biomarker of Clinical Status...

*Mismatch is the key...*

Acute Lesion Volumes Correlated with Clinical Scales and with Final Lesion Volumes...

<table>
<thead>
<tr>
<th>Clinically</th>
<th>% Pts with</th>
<th>Median Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved?</td>
<td>Lesion Decrease</td>
<td>cm³ +/- SE</td>
</tr>
<tr>
<td>Yes</td>
<td>74</td>
<td>-2.8 +/- 3.8</td>
</tr>
<tr>
<td>No</td>
<td>36</td>
<td>3.7 +/- 25.5</td>
</tr>
</tbody>
</table>


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DWI PWI: Why Map Perfusion?

**Scan Parameters**
- **GRE-EPI images acquired during bolus injection.**
- 12 slices every 2 sec.
- 40 phases over 80 sec.
- 0.1 mmol/kg Gd - Power injector.
- 1.5 mm per pixel resolution.
- as for T2, FLAIR, DWI, PWI.

- **Maps of rCBV, rMTT, rCBF from transit.**
- Arterial input needed.

MRI for the CNS Patient

High-field 1.5 Tesla EPI-ready MR scanner

- **Scout**
  - 1:21 sag. coverage

- **MRA**
  - 3:06 w/o contrast

- **DWI EPI**
  - 1:30 b0, b1000, IR

- **GRE EPI**
  - 0:06 bleed screen

- **T2 FSE/FLAIR**
  - 3:45 T2-wt. FLAIR

- **CE MRA**
  - 1:30 contrast MRA

- **PWI EPI**
  - 0:80 bolus-tracking

- **T1 SE**
  - 1:40 hemorrhage

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Is There a Need for CBF Quantitation?

**Vol DWI (7 days)/Vol DWI (5 hrs)**

*(Thijs, et al) 72yro - Stenosis MRI at 5hr - ADVANCE 13*
**PWI/DWI Patterns**

- **PWI lesion > DWI lesion**
- **PWI lesion = DWI lesion**
- **PWI lesion < DWI lesion**

*ADC is reversible if reperfused early.*

**DWI in Stroke: Ready for Primetime?**

- DWI highly-specific for cerebral stroke.
- ADC drops acutely *(up to 50% of normal).*
- ADC increases slowly over 7-10 days.
- ADC drops with perfusion deficits.
  - Threshold exists *(10-15 ml/100gm/min).*
  - ADC = inherent measure of CBF.
- ADC values predicts infarction/bleeds.
- ADC is reversible if reperfused early.

**Magnetic Resonance Imaging of Acute Stroke: Predictor of Outcome?**

- Chelsea S. Kidwell, MD; Jeffrey L. Saver, MD; Jeffry R. Alger, PhD; Fernando Vinuela, MD, et al.

**Pretreatment ADC Values**

- No Reversal
- Reversal, Late Secondary Injury
- Sustained Reversal

*P* < 0.001

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**Evolving Roles for DWI**

**Beyond clinical stroke...**

**DWI in Acute Trauma...**
Huisman, et al. MGH

*DWI effective in detecting shearing injuries and early DAI...Of 427 lesions, DWI detected 70 not seen on T2W or FLAIR...*

**DWI Beyond Clinical Stroke**

4 y.o. male, 3 days s/p MVA, decreasing mental status, UE weakness

**Dwi in Pediatrics**

3 cases:
- Cord Nuchal.
- Skull (forecpeps) fracture.
- Cord Nuchal.

**J. Neil, et al.**
Wash. Univ Radiology, 1998

**Elevating Roles for DWI**

**Beyond clinical stroke...**

Pediatric stroke and trauma
Washington University, St. Louis

*DWI ideal for depiction of neonatal ischemia, hypoxia, trauma...*
**Evolving Roles for DWI**

*Not just for (adult) clinical stroke...*


*DWI ideal for monitoring of SCD in children*

12 yom

SCD

6 days

T2-weighted TGSE

FLAIR DW-EPI

ADC_

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**Evolving Roles for DWI**

*Beyond clinical stroke...*

DWI in Transient events...Sorensen, et al. MGH

DWI showing promise in migraine. Several documented cases of reversal.

3 days

Hemiplegic Migraineur

7 days

T2 ADC DWI

G. Sorensen, MGH

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**Evolving Roles for DWI**

*Beyond clinical stroke...*


DWI - abnormalities seen in 16 of 78 cases (21%).

DWI + scans 10 times more likely to have duration >1hr.

16 times more likely to have had motor deficits

25 times more likely to have had aphasia.

All 3 symptoms 100% specific for an abnormality on DWI.

Many other studies...hot topic for diagnosis/prognosis.