DWI
in Body Applications

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Outline

• What is diffusion imaging?
• Why diffusion imaging?
• What are the current applications?
• What is new in diffusion?
“There is an extraordinary opportunity for DW-MRI to evolve into a clinically useful method that is useful for pharmaceutical drug development and for predicting therapeutic efficacy”

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• What is diffusion imaging?
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What is diffusion?

- Measures motion of water molecules (Brownian motion)
- Due to thermal agitation
- Influenced by:
  - cellularity
  - intracellular elements
  - membranes
  - macromolecules
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• **Why diffusion imaging?**
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Why Diffusion Imaging?

- Non-invasive
- Intrinsic (no contrast needed)
- Fast (BH)
- Large anatomic coverage
- Quantifiable (ADC value)
- Tissue-specific
Diffusion Imaging Technique

- TR/TE 3000/77
- B value = 50, 750
- Averages = 1
- Resolution = 128 x 128
- FOV = 340 x 255
- Acquisition Time = 23s
- Slices = 20
- ST = 8 mm
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Current Applications

Liver

I. Focal lesions:
   1. Improved lesion detection
   2. Better lesion characterization
   3. Tumor response to treatment

II. Parenchymal disease:
   Hepatic fibrosis/inflammation

Others: Kidney, pancreas, breast, uterus, prostate
1. Lesion Detection

T2  DWI  HAP
### 2. Lesion Characterization

#### Qualitative Assessment

<table>
<thead>
<tr>
<th>SI high b-value</th>
<th>SI ADC</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>low</td>
<td>high cellularity</td>
</tr>
<tr>
<td>high</td>
<td>high</td>
<td>T2-shine</td>
</tr>
<tr>
<td>low</td>
<td>high</td>
<td>low cellularity</td>
</tr>
<tr>
<td>low</td>
<td>low</td>
<td>fibrosis</td>
</tr>
</tbody>
</table>

3. Tumor Response
Current Response Criteria

• Tumor size (WHO, RECIST*)
  – Only published criteria
  – Not useful after loco-regional therapy

• Tumor enhancement (EASL**)
  – Enhancement = viability
  – May not be useful in hypovascular mets

*Therasse P et al, JNCI (2000); 92: 205-216
**Bruix et al. J. Hepatology (2001); 35:421-430
ADC: Biomarker of Response

• Rationale:
  – Inverse correl. between ADC & tumor cellularity
    • Gauvain KM et al, AJR (2001) 177: 449
  – Change in cellularity >> change in ADC
    • Guo Y et al, JMRI (2002) 16: 172
  – Change in ADC occurs before change in size
    • Kamel IR et al, JVIR (2006) 17: 505
  – ADC correlates with necrosis in Vx2 rabbit model
  – f map may predict survival
    • Moffat B et al, PNAS (2005) 102: 5524
ADC: Biomarker of Response

• **Image Analysis**
  - Mean tumor ADC: Simplest
    • Global change
    • Kamel IR et al. JVIR (2006) 17: 505
  - Histogram analysis:
    • Fractional volume above/below certain threshold
    • Koh DM et al. AJR (2007) 188: 1001
  - Functional diffusion map: Most challenging
    • Allows voxel-by-voxel analysis, regional response
    • Moffat B et al. PNAS (2005) 102: 5524
Can ADC Predict Response?

3 wks after Treatment

- Functional diffusion map stratification correlated with OS in brain glioma (Hamstra DA et al, PNAS 2005; 102:16759)

Before Treatment

- Lower pre-treatment ADC >> better response of colorectal mets (Koh DM et al, AJR 2007; 188:1001)
II. Parenchymal Disease

- Liver fibrosis and inflammation
- BH single shot EPI: conventional DWI and diffusion tensor imaging
- B= 0 and 500
- Chronic liver disease (n = 31), normal volunteers (n = 13)
- Conventional DWI better than DTI
- ADC ≤ 1.30 x 10^-3 mm²/sec
- Predicting stage ≥ 1 fibrosis and inflammation, RUC was 0.848 and 0.825, resp.

Taouli et al, *JMRI* (2008) 28; 89-95
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• NCI-sponsored consensus at ISMRM 2008
  – Recommended DWI as a biomarker in clinical trials
  – Should be compared with histology
  – Use 2 b values (>100 and 500-1000 mm²/sec)
  – Free breathing is superior to gating technique
  – Base line reproducibility studies should be performed
  – Standardize acquisitions and image processing

Padhani et al, Neoplasia (2009) 11, 102-125
There is an extraordinary opportunity for DW-MRI to evolve into a clinically useful method that is useful for pharmaceutical drug development and for predicting therapeutic efficacy.

DWI: Challenges

- Rapid technology evolution
- Divergence between vendors
- Lack of standards for measurements and analysis
- Lack of understanding of changes at microscopic level
- Multiexponential decay affects calculated ADC
- Need for tissue-mimicking phantom
- Incomplete validation and documentation of reproducibility
DWI: When to image after TACE?

Kamel et al. Radiology (2009) 250; 466-473
DWI: Other Organs

• Myometrial invasion in endometrial ca
  – Lin et al, Radiology (2009) 230;784-792

• Detecting gallbladder ca
  – Sugita et al, Eur Rad online Feb 2009

• Detecting esophageal ca
  – Sakurada et al, Eur Rad online Feb 2009

• Breast: tissue adjacent to breast ca
  – Yili et al, BMC Cancer (2009) 9; 18

• Adrenal tumors
  – Tsushima et al, JMRI (2009) 29; 112-117
DWI: Whole Body Diffusion

72 year old with colon cancer metastases

Courtesy: M. A. Jacobs, PhD, Johns Hopkins
DWI: Whole Body Diffusion

72 year old with colon cancer metastases

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3T: Reproducibility of ADC

- 20 healthy male volunteers
- 5 axial abdominal acquisitions
- Repeated after 147 +/- 20 days
- ADC measured in 5 locations: liver, spleen, pancreas (head, body, tail)
- Calculated mean ADC and coeff. of variability (CV)
- CV = 14%

DWI @ 3T

BH; B: 0 and 750

BH; B: 50 and 600

FB; B: 0 and 750

FB; B: 50 and 600
Conclusions

• DW-MRI is a functional imaging technique that is linked to lesion aggressiveness.
• It has a number of potential roles including detection and characterization of cancers.
• DW-MRI is a potential imaging biomarker for the assessment of tumor response to therapy.
• Several challenges exist and need to be addressed.