Diffusion MRI of the Abdomen

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Diffusion Imaging

• Random motion of molecules
• Scale of motion is microscopic
• Requires application of strong gradients to detect
• Quantified as “ADC” (apparent diffusion coefficient)
**Diffusion MRI of Abdomen**

- Theory is that malignant lesions (but not benign ones) have restricted diffusion
- Typically use mono-directional diffusion gradient with b value of 0 or 50 and ~500 and 1000
- Calculate apparent diffusion coefficient (ADC) map from images with two or more different b values
- Diffusion MRI only increases exam duration by a few seconds (breath-hold) to a few minutes (respiratory-gated)
### Diffusion MRI of Abdomen

**Technical Considerations**

<table>
<thead>
<tr>
<th>Imaging Parameters for Breath-hold and Respiratory-triggered DW MR Imaging</th>
<th>Breath-hold</th>
<th>Respiratory-triggered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition time/echo time (msec)</td>
<td>1500/73</td>
<td>3500/73</td>
</tr>
<tr>
<td>Receiver bandwidth (Hz/pixel)</td>
<td>1736</td>
<td>1736</td>
</tr>
<tr>
<td>Matrix</td>
<td>$156 \times 192$</td>
<td>$156 \times 192$</td>
</tr>
<tr>
<td>Section thickness (mm)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Intersection gap (mm)</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>No. of signals acquired</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Field of view (mm)</td>
<td>$350 \times 240–280$</td>
<td>$350 \times 240–280$</td>
</tr>
<tr>
<td>Echo train length</td>
<td>123</td>
<td>123</td>
</tr>
<tr>
<td>Echo train spacing (msec)</td>
<td>0.69</td>
<td>0.69</td>
</tr>
<tr>
<td>Parallel imaging factor*</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Acquisition time per stack (sec)</td>
<td>27</td>
<td>95–158†</td>
</tr>
<tr>
<td>No. of sections per stack</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>No. of stacks</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

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*Performed by using k-space–based technique (generalized autocalibrating partially parallel acquisition [GRAPPA]; Siemens Medical Solutions).

†Variable depending on respiratory cycle.

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Kim SY et al. Radiology 2010; 255:815
Diffusion MRI of Abdomen
How Reproducible are ADC Measurements?

- Study of 49 malignant liver lesions (43 HCC, 3 colon Ca mets, 3 cholangioCa) at 1.5T
- When ADCs of malignant hepatic tumors are used for monitoring treatment response, changes in ADC of approximately 30% or greater should be considered to be beyond the range of measurement error.
- ADCs of respiratory-triggered DWI were higher than breath-hold DWI (possibly due to effect of respiratory motion with respiratory triggering)
- Reproducibility of measurements affected by location and size of lesion (e.g. poor reproducibility for left lobe lesions)

Kim SY et al. Radiology 2010; 255:815
• 211 focal liver lesions (136 malignant, 75 benign)
• Overall detection rate was significantly higher for DWI (87.7%) versus T2-weighted (70.1%) imaging, particularly for small malignant lesions (1-3cm) and small (50) b value
• FLL characterization was not significantly different between DW (89.1%) and T2-weighted (86.8%) imaging.
• ADCs of malignant FLLs (1.39x10^{-3} mm^2/sec) were significantly lower than those of benign FLLs (2.19x10^{-3} mm^2/sec)
• Respiratory-triggering better than breath-holding
• No difference in DWI lesion detection for right vs. left lobes, but T2w worse in left lobe

Parikh T et al. Radiology 2008; 246:812
Diffusion MRI of Abdomen
Does It Improve Lesion Detection?

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**Diffusion MRI of Abdomen**

What is Specificity for Distinguishing Malignant from Benign Lesions?

- 43/55 lesions with restricted diffusion were malignant
- 12/55 with restricted diffusion were benign:
  - liver hemangioma, liver adenoma, autoimmune pancreatitis, pancreatic teratoma, abscess, inflammatory bowel wall thickening due to Crohn’s disease, Bartholin cyst, hemorrhagic ovarian cyst, and renal Rosai-Dorfman disease

Feuerlein S et al. *AJR* 2009; 193:1070
Study of DWI at Northwestern Memorial Hospital

- 577 lesions in 380 patients (from September 2005-July 2007)
- Variety of lesions
  - 166 Hemangiomas, 147 Hepatomas, 107 Metastases, 95 Cysts, 43 FNH, 10 Abscesses, 9 Adenomas

Courtesy Dr. Frank Miller
ADC OF LIVER LESIONS

- Metastasis
- HCC
- FNH
- Adenoma
- Abscess
- Hemangioma
- Cyst
DISCUSSION

- Using <1.5: sensitivity 53%; specificity 91%; PPV 81% and NPV 74% for malignancy
- Over 90% of benign lesions had ADC above 1.5
  - Relates to majority of benign lesions being cysts or hemangiomas
  - These can generally be diagnosed with conventional imaging including high SI on T2 and contrast-enhancement
SUMMARY OF LIVER DIFFUSION

- Malignant lesions have more restricted diffusion than cysts and hemangiomas
- This can help in detecting lesions but not always for characterization
- ADC values of solid benign hepatocellular lesions (FNH and adenomas) are similar to malignant lesions (HCC and mets)
• 46 patients with colorectal cancer
• Malignant nodes had lower ADC than benign ones (1.36 vs. 1.85 x 10-3 mm2/sec)
• Best discrimination was obtained using ratio of LN to primary tumor ADC (LN/T).
• LN/T ratio cutoff of 1.495 gave accuracy of 78.5%

Diffusion MRI of Abdomen
Utility for Distinguishing Malignant from Benign Lymphadenopathy in Patients with Prostate Cancer

- 29 patients with prostate cancer
- ADC ($\times 10^{-3}$mm$^2$/s) of malignant lymph nodes (1.07±0.23) was lower than benign (1.54±0.25) lymph nodes
- ADC had accuracy of 85.5%; sensitivity of 81.1%; specificity of 89.1% for differentiation of malignant versus benign lymph nodes, which was superior to size-based analysis (accuracy:66.1%)

Early change in ADC post-treatment, prior to change in tumor volume, may predict response to chemotherapy.
• Cirrhotic liver has a lower ADC than normal liver
• Patients with moderate to severe fibrosis (F2–F4) had hepatic ADC values lower than those without or with mild fibrosis (F0 or F1) and healthy volunteers: 1.10 ± 0.11 versus 1.30 ± 0.12 versus 1.44 ±0.02 × 10⁻³ mm²/s, respectively.
• Sensitivity, specificity, positive predictive value, and negative predictive value were 87%, 87%, 72%, and 94%, respectively, for the diagnosis of advanced fibrosis and cirrhosis (F3–F4) using an ADC cutoff of 1.21 ×10⁻³ mm²/s.
• Cause of decreased ADC in cirrhosis may be reduced perfusion.

Reeder S et al. AJR 2009; 193:14