Basics of MRI – in practice

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Magnetic Resonance Imaging

- Protons aligned with B0 magnetic field
- Longitudinal magnetization - T1 relaxation
- Transverse magnetization - T2 relaxation
- Signal measured in the transverse plane

<table>
<thead>
<tr>
<th>Tissue</th>
<th>T1 (ms)</th>
<th>T2 (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water/CSF</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td>Gray matter</td>
<td>900</td>
<td>80</td>
</tr>
<tr>
<td>Muscle</td>
<td>900</td>
<td>50</td>
</tr>
<tr>
<td>Liver</td>
<td>500</td>
<td>40</td>
</tr>
<tr>
<td>Fat</td>
<td>250</td>
<td>70</td>
</tr>
<tr>
<td>Tendons</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td>Proteins</td>
<td>250</td>
<td>0.1 - 1.0</td>
</tr>
<tr>
<td>Tis</td>
<td>5000</td>
<td>0.001</td>
</tr>
</tbody>
</table>

In biological tissues T1>T2

Generation of MR signal

- Longitudinal magnetization - T1 relaxation
- Transverse magnetization - T2 relaxation
- The two happen simultaneously
- magnetization ≠ signal

Free induction decay

What does short T2 mean?

Short T2
Long T2

Spin echo imaging

The magnetic vector is "echoed" by the 180 deg pulse
Spin echo

Signal decrease by T2

Image weighting – effect of TR

From T1

- TE=10 TR=400
- TE=10 TR=1000
- TE=10 TR=1800
- TE=10 TR=2600
- TE=10 TR=3000

To Proton Density

Image weighting – effect of TE

From Proton Density

- TE=10 TR=3000
- TE=40 TR=3000
- TE=70 TR=3000
- TE=90 TR=3000
- TE=150 TR=3000

To T2
Conventional SE T1-weighted scan

- Anatomy
- 2D or 3D
- Resolution: 0.9-8mm3
- Tissues:
  - CSF: dark
  - WM: light grey
  - GM: dark grey
  - Lesions: bright/dark
- The T1 weighting is optimized for the T1 differences of tissues in the given body part.

3D T1 advantages: resolution

<table>
<thead>
<tr>
<th>2D T1</th>
<th>3D T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25x1.25x5mm</td>
<td>0.9x0.9x1mm</td>
</tr>
</tbody>
</table>

3D T1 advantages: Multi Planar Reconstructions (MPR)

Conventional T2-weighted scans

- 2D
- Resolution: 1.5-7mm3
- Lesion characterization
- CSF spaces, fluid collection, edema
- Tissues:
  - CSF: bright
  - WM: dark grey
  - GM: light grey
  - Lesions: mostly bright

Inversion recovery sequences

- Nulling time of a tissue is 0.69 x T1 time
- If T1=400ms what is the suppressed tissue?
Inversion recovery sequences

http://mriquestions.com/

T1 IR
ST IR
FLAIR IR


STIR

Lower resolution for higher signal: smaller matrix size, but keep slice thickness

Contrast-enhanced (?) STIR

Contrast-enhanced STIR
Contrast-suppressed STIR


Other fat suppression techniques in spine

Fat saturation: frequency-selective saturation of fat signal

Why do CE spine with fat suppression?

Other fat suppression techniques in spine

Why do CE spine with fat suppression?

Other fat suppression techniques in spine

Standard T1 CE

mDixon T1 CE

2D or 3D

Resolution: 1.8-2.6mm3

Tissues:
- CSF: no signal (T2!) 
- WM: dark grey
- GM: lighter grey
- Lesions: bright

Fluid Attenuated Inversion Recovery (FLAIR)

Lesion characterization

2D or 3D

Resolution: 1.8-2.6mm3

Tissues:
- CSF: no signal (T2!)
- WM: dark grey
- GM: lighter grey
- Lesions: bright
3T Philips 2D FLAIR vs. 3D FLAIR

<table>
<thead>
<tr>
<th></th>
<th>2D</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition</td>
<td>Axial/Sagittal</td>
<td>Axial/Sag/Cor</td>
</tr>
<tr>
<td>Thickness</td>
<td>4mm axi 3mm sag</td>
<td>2mm</td>
</tr>
<tr>
<td>Gap</td>
<td>1mm</td>
<td>-1mm</td>
</tr>
<tr>
<td>In plane res.</td>
<td>0.74x0.86 axi 0.8x0.88 sag</td>
<td>0.9x0.9</td>
</tr>
<tr>
<td>Pulsation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scan length</td>
<td>4:30 min axi 5:30 min sag</td>
<td>4:47 min</td>
</tr>
</tbody>
</table>

3D: Thin slice

3D: No pulsation artifact

2D: False positive from pulsation artifact
3D: Thin slice, no pulsation artifact

2D  
3D

3D: Thin slice, no pulsation artifact

2D  
3D

SWI – phase map

Local differences (susceptibility)

Inhomogeneity of B0

Geometry

Magnitude Image x Phase mask = SWI image


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Magnitude Image x Phase mask = SWI image

Magnitude

Mask

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SWI: Effect of filter size

Filter: 32

Filter: 256

Effect of flip angle

TE:40ms, TR:60ms

FA:10°

FA:15°

FA:18°

FA:20°

Signal Intensity:

FA:10°: 130.55 ± 8.21

FA:15°: 193.13 ± 10.71

FA:18°: 215.76 ± 7.25
Effect of bandwidth

- TE: 40ms, TR: 60ms, FA: 20°
  - BW: 72Hz/pixel
    - SI: 238.23 ± 6.65
  - BW: 108Hz/pixel
    - SI: 215.76 ± 7.25

Effect of bandwidth

- TE: 40ms, TR: 60ms, FA: 10°
  - BW: 72Hz/pixel
    - SI: 172.85 ± 8.39
  - BW: 108Hz/pixel
    - SI: 130.94 ± 7.30

Effect of repetition time

- TE: 40ms, BW: 72Hz/min, FA: 20°
  - TR: 50ms
    - SI: 267.05 ± 7.15
  - TR: 60ms
    - SI: 238.23 ± 6.65

Effect of repetition time

- TE: 40ms, BW: 72Hz/min, FA: 20°
  - TR: 50ms
    - SI: 247.08 ± 9.73
  - TR: 60ms
    - SI: 238.23 ± 6.65

Susceptibility Weighted Imaging (SWI)

- Sensitive for:
  - Venous blood (MRV)
  - Blood products
  - Calcifications

- Indications:
  - Trauma
  - Stroke
  - Amyloid angiopathy
  - Venous anomalies
  - DVA
  - Cavernoma
  - Postirradiation telangiectasia

DRIVE

- 3D T2
  - High contrast between CSF and parenchyma
  - Poor tissue contrast

- Indications:
  - Cranial nerves: 3, 5, 6, 7&8, 9
    - Vestibular Schwannoma
    - Meningioma
    - Trigeminal neuralgia
    - Neurovascular compressions
    - IAC and inner ear
Neurovascular compression

Same geometry: FOV=15cm, matrix=300x300, thk=1mm, space=-0.5mm

DRIVE

TOF MRA

Merge of DRIVE+TOF

MRA of the head – Time-of-flight (TOF)

Indications
• Rule out aneurysm
• Other vascular anomalies with high velocity flow (moya moya, AV fistula)
• Intracranial stenosis (less precise)

Not good for DVA!

3D MR angiography
CMW and vertebrobasilar arteries
5-6 mins
No contrast!
Sensitive for high velocity flow

MRV – Phase contrast

Sensitive for
Direction of flow
Velocity of flow

Indications
Imaging of intracranial veins
“Slow flow”
Sinus thrombosis
Sinus thrombosis vs Hypoplasia

Gadolinium contrast is not necessary in most cases!

Clinical MRI protocols - Routine brain

Indication
Non-specific symptoms
Rule out: tumor, inflammation, demyelinating disease, vascular lesions, CVJ abnormalities, Chiari, headache.

3D T1

T2 axi and cor, DWI

3D FLAIR
**Headache/dizziness**

**Indications**
- Dizziness / vertigo as leading symptoms
- Cranial nerves: 3, 5, 6, 7&8, 9
- Vestibular Schwannoma
- Meningioma
- Trigeminal neuralgia
- Neurovascular compressions
- A&lt;sup&gt;4&lt;/sup&gt; is too small (mostly)
- IAC and inner ear

**Trauma**

**Indications**
- Head trauma

**Gadolinium contrast is not necessary in most cases!**

**Tumor**

**Indications**
- Newly discovered tumor
- Tumor follow-up
- Tumor patient with Dizziness
- Headache
- Seizure

**Contrast-enhanced study!**

**Seizure**

**Indications**
- Focal cortical dysplasia
- Other GM abnormality
- T2, FLAIR
- Any abnormality
- CSF spaces
- Coronal FLAIR and IR
- Hippocampal sclerosis
- GM abnormalities
- Aligned with hippocampus

**Gadolinium contrast is not necessary in most cases!**

**Dementia w volumetrics**

**Multiple Sclerosis - 1.5T**

**Indications**
- Known MS follow-up

**Contrast-enhanced study!**
**Multiple Sclerosis - 3T Philips**

- 2D T2, DWI
- Sag 3D FLAIR
- 3D T1
- 3D CE T1

**Pituitary**

*Contrast-enhanced study!*

**Most frequent indications**
- Rule out / follow-up microadenoma
- Follow-up macroadenoma (1-2cm)
- Posterior lobe anomalies (diabetes insipidus)

*Not for craniopharyngeomia!*

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