MRI Protocols in Experimental Stroke

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Objective

- In Multi-PART magnetic resonance imaging (MRI) data from different scanners will be combined.
- Effective pooling will require standardisation of acquisition protocols and post-processing methods.

We aim to examine the variability in the use of MRI in animal models of stroke for measuring the infarct size, and develop standardised strategies to facilitate multicentre studies.
Do you use the following to assess infarct volume?

- **TTC**
  - Yes: 62%
  - No: 38%

- **MRI**
  - Yes: 67%
  - No: 33%

- **Histology**
  - Yes: 97%
  - No: 3%
Type of Histology?

- Cresyl Violet
- H&E
- Thionin
- Silver
- Immunohistochemistry
- NeuN
- Nitroblue tetrazolium (NBT)
- Luxol fast blue

0 10 20 30
Systematic review of MRI in experimental stroke

54 articles identified in CAMARADES meta-analysis database

78 scanning protocols for the assessment of lesion sizes:
- T2-weighted imaging: 45
- Diffusion-weighted imaging: 23
- T1-weighted imaging: 4
- Perfusion-weighted imaging: 3
- Plasma volume imaging: 2
- Unknown: 1

46 comparisons between MRI and histology:
- T2-weighted imaging: 33
- Diffusion-weighted imaging: 11
- T1-weighted imaging: 4
- Perfusion-weighted imaging: 4
- TTC: 41
- Hematoxylin & eosin: 4
- Cresyl violet: 1

Evaluate the heterogeneity and reporting of MRI parameters

Identify which MRI method best correlates with histology using meta-regression
Study quality

Peer-reviewed publication
Control of temperature
Compliance with animal welfare regulations
Use of anaesthetic without marked intrinsic neuroprotective activity
Random allocation to groups
Blinded assessment of outcome
Statement of potential conflicts of interest
Blinded induction of ischemia
Use of comorbid animals
Sample size calculation

Prevalence (%)
Basic imaging characteristics (1)

Type of radiofrequency coil

- Two types: 36%
- Volume: 36%
- Surface: 25%
- Human wrist: 4%

52% of studies

Other conditions:
- Temperature & other
- Temperature

Anaesthetic for MRI:
- 63% of studies
- FFM

Basic imaging characteristics (1)

- Magnet field strength (Tesla) 94% of studies
- Monitoring during scanning 30% of studies
- Type of radiofrequency coil 52% of studies
- Temperature 25% of studies
- Other conditions 32% of studies

Radiofrequency coil types:
- Ketamine
- Isoflurane
- Halothane
- Pentobarbital
- FFM

Human wrist:
- Surface
- Volume
- Two types

Percentages (%)

Human wrist:
- Surface
- Volume
- Two types

Other conditions:
- Temperature & other
- Temperature

Anaesthetic for MRI:
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Magnet field strength (Tesla) 94% of studies

Monitoring during scanning 30% of studies

Type of radiofrequency coil 52% of studies

Radiofrequency coil types:
- Ketamine
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- Halothane
- Pentobarbital
- FFM

Human wrist:
- Surface
- Volume
- Two types
Basic imaging characteristics (2)

Presentation of lesion size
99% of studies

- **Volume**: 58%
- **Compared to ipsi**: 18%
- **Change from baseline**: 9%
- **Compared to contra**: 8%
- **Compared to brain**: 5%
- **Area at one slice**: 1%

# MRI scanning parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>T2-weighted imaging</th>
<th>Diffusion-weighted imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>median</td>
</tr>
<tr>
<td><strong>Echo time (ms)</strong></td>
<td>30-120</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>30-120</td>
<td>66</td>
</tr>
<tr>
<td><strong>Repetition time (ms)</strong></td>
<td>1750-8000</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td>1000-3000</td>
<td>2550</td>
</tr>
<tr>
<td><strong>Number of slices</strong></td>
<td>6-35</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>5-25</td>
<td>13</td>
</tr>
<tr>
<td><strong>Slice thickness (mm)</strong></td>
<td>0.35-3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.5-1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Field of view (mm×mm)</strong></td>
<td>22×22-120×120</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>25.6×12.8-20×20</td>
<td>-</td>
</tr>
<tr>
<td><strong>Matrix size (pixels×pixels)</strong></td>
<td>64×64-512×512</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>128×64-256×256</td>
<td>-</td>
</tr>
<tr>
<td><strong>Number of averages</strong></td>
<td>2-8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>8-16</td>
<td>12</td>
</tr>
</tbody>
</table>
### T2-weighted imaging correlates with histology

<table>
<thead>
<tr>
<th>Method</th>
<th>Time post-stroke (h)</th>
<th>Compar.</th>
<th>n</th>
<th>Effect size [95% CI] (%)</th>
<th>Meta-regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coeff.</td>
</tr>
<tr>
<td>Histology</td>
<td>48 - 336</td>
<td>33</td>
<td>210</td>
<td>25.49 [17.52, 33.46]</td>
<td>1.08</td>
</tr>
<tr>
<td>T2WI</td>
<td>21 - 174</td>
<td>11</td>
<td>105</td>
<td>31.85 [24.02, 39.68]</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>147</td>
<td>42.43 [30.88, 53.98]</td>
<td></td>
</tr>
</tbody>
</table>
Assessment of MRI using a structural phantom

Internal dimensions
Assessment of scaling in 3 directions

Cylindrical volume
Assessment of acquisition parameters

\[ \sum_{i=1}^{n} \text{Area}_i \]
Differences between pulse sequences

7T Agilent preclinical scanner, 120mm bore gradient coil, 72mm (ID) volume transmit & 2 channel mouse phased array surface receive coil

Fast spin echo (FSE) vs. Gradient echo (GE)
(19.2x19.2mm FOV, 256x256 matrix, 1mm slice thickness, 2 averages)
Impact of scanning parameters on volume measurements

Fast spin echo (TR/TE$_{\text{eff}}$=1500/20ms, 19.2×19.2mm FOV, 256×256 matrix, 1mm slice thickness, ETL=4, 2 averages)

...then changed one parameter at a time

- 69%
- 14%
Within- and between-scanner variability

Edinburgh Preclinical Imaging (EPI)
7T Agilent scanner

Glasgow Experimental MRI Centre (GEMRIC)
7T Bruker scanner

![Graph showing scaling error (%) over time for EPI and GEMRIC.](image)
Future plans...

Assessment of MRI acquisition protocols using the phantom
- Other pulse sequences
- Other coils
- Other scanners

Assessment of post-processing methods for calculating the infarct size from animal data
- Evaluate performance based on ground truth (manual, histology?)
- Estimate between-method variation

Survey under construction...