Systematic Review of Perfusion Imaging With Computed Tomography and Magnetic Resonance in Acute Ischemic Stroke: Heterogeneity of Acquisition and Postprocessing Parameters

A Translational Medicine Research Collaboration Multicentre Acute Stroke Imaging Study

Krishna A. Dani, MRCP; Ralph G.R. Thomas, MRCP; Francesca M. Chappell, PhD; Kirsten Shuler, BSc; Keith W. Muir, MD; Joanna M. Wardlaw, MD

Background and Purpose—Heterogeneity of acquisition and postprocessing parameters for magnetic resonance– and computed tomography–based perfusion imaging in acute stroke may limit comparisons between studies, but the current degree of heterogeneity in the literature has not been precisely defined.

Methods—We examined articles published before August 30, 2009 that reported perfusion thresholds, average lesion perfusion values, or correlations of perfusion deficit volumes from acute stroke patients <24 hours postictus. We compared acquisition parameters from published studies with guidance from the Acute Stroke Imaging Research Roadmap. In addition, we assessed the consistency of postprocessing parameters.

Results—Twenty computed tomography perfusion and 49 perfusion-weighted imaging studies were included from 7152 articles. Although certain parameters were reported frequently, consistently, and in line with the Roadmap proposals, we found substantial heterogeneity in other parameters, and there was considerable variation and underreporting of postprocessing methodology.

Conclusions—There is substantial scope to increase homogeneity in future studies, eg, through reporting standards.

Key Words: perfusion ■ magnetic resonance imaging ■ computed tomography

Computed tomography perfusion (CTp) and magnetic resonance (MR)–derived perfusion-weighted imaging (PWI) hold promise for patient selection for reperfusion therapies in ischemic stroke by defining tissue viability. However, clinical trials that use perfusion imaging to support an extended time window for thrombolysis have, to date, been inconclusive. Although this may be because of a number of methodological issues related to perfusion thresholds, relative and absolute tissue compartment volumes, and definitions of tissue at risk, it may also reflect differences in acquisition and postprocessing of perfusion data. Indeed, the Acute Stroke Research Imaging Roadmap consensus statement has recently encouraged adherence to common acquisition protocols. In this study, we assessed the heterogeneity of current perfusion-based stroke studies to evaluate current practice and variation within the literature.

Methods

Search Strategy

The search strategy and data extraction, which incorporated manuscripts published up to August 2009, have been described in detail elsewhere. Manuscript selection criteria for this study were:

1. English Language
2. Adult (age ≥18 years) stroke patients <24 hours postictus, distinguishable from other patients described in publications by the same research group
3. Report of perfusion characteristics from studies using either first-pass CTp or MR-derived PWI for the following:
   a. Threshold values for tissue compartments
   b. Mean perfusion values in different tissue compartments
   c. Correlation of deficit volumes on perfusion imaging with lesions on other imaging modalities

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Exclusion Criteria

1. Subjects with hemorrhagic stroke, venous infarction, or chronic occlusive cerebrovascular disease.
2. Studies of perfusion techniques other than first-pass bolus tracking CTp or MR-PWI, e.g., arterial spin labeling, CTp from triphasic helical technique, or other steady-state techniques.
3. Studies of technical development/optimization of imaging parameters for CT or PWI techniques.
4. Studies using both duplicate data and analyses from other larger included studies.

Comparison to Roadmap Criteria

Acquisition parameters from CTp and PWI studies were compared with those stated by the Acute Stroke Imaging Research Roadmap (Table 1) and graded as consistent, inconsistent, or not reported. The reporting of postprocessing parameters was also considered.

Results

A review of 7153 articles yielded 49 MR-PWI articles and 20 CTp articles (Supplemental Table; http://stroke.ahajournals.org). The manuscripts of all but 3 studies were received by the publishing journal before publication of the Roadmap.

Although several parameters were consistent with the Roadmap, acquisition parameters were heterogeneous, sometimes with a large range noted (Table 2). For example, in CT studies, there were: number of slices ranging from 1 to 4; rate of injection ranging from 2 to 20 mL/s; electric parameters of 9 different combinations of peak kilovoltage and milliamperes; and for volume of iodine in contrast, 8 combinations in 10 papers, ranging from 10.5 to 18.5 g. For MR studies, there were: 24 combinations of echo time/repetition time, number of phases of acquisition ranging from 20 to 60 phases, and number of slices ranging from 7 to 40s. Postprocessing parameters were also heterogeneous (Table 2).

Discussion

In CT and magnetic resonance imaging perfusion studies, many acquisition and postprocessing parameters are frequently unreported or heterogeneous. The impact of the observed heterogeneity is likely to be complex, and when combined with variable definitions of penumbra, may explain, at least in part, the failure to replicate promising initial results using imaging selection and end points when CTp and PWI are undertaken across multiple centers. The effect of underreporting is less clear, but the Roadmap proposals now give future authors the opportunity to state, at least in a generic manner, that such acquisition parameters have been
Table 2. Analysis of Study Acquisition and Postprocessing Parameters

<table>
<thead>
<tr>
<th>Acquisition Parameter</th>
<th>MR Studies</th>
<th>CT Studies</th>
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<tbody>
<tr>
<td></td>
<td>Consistent, n (%)</td>
<td>Not Consistent, n (%)</td>
</tr>
<tr>
<td>Type of sequence</td>
<td>13 (26)</td>
<td>18 (37)</td>
</tr>
<tr>
<td>Duration</td>
<td>3 (6)</td>
<td>31 (63)</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>26 (53)</td>
<td>10 (20)</td>
</tr>
<tr>
<td>TR</td>
<td>3 (6)</td>
<td>38 (78)</td>
</tr>
<tr>
<td>Field of view</td>
<td>21 (43)</td>
<td>18 (37)</td>
</tr>
<tr>
<td>Avoidance of lenses</td>
<td>2 (10)</td>
<td>2 (10)</td>
</tr>
<tr>
<td>Anatomic coverage</td>
<td>24 (49)</td>
<td>19 (39)</td>
</tr>
<tr>
<td>Slice thickness</td>
<td>26 (53)</td>
<td>18 (37)</td>
</tr>
<tr>
<td>Contast type</td>
<td>45 (92)</td>
<td>4 (8)</td>
</tr>
<tr>
<td>Contrast concentration</td>
<td>25 (51)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Injection delay</td>
<td>2 (4)</td>
<td>12 (25)</td>
</tr>
<tr>
<td>Injection rate</td>
<td>24 (49)</td>
<td>10 (20)</td>
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<tr>
<td>Power injector used</td>
<td>4 (8)</td>
<td>18 (37)</td>
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<tr>
<td>Cannula gauge</td>
<td>10 (5)</td>
<td>1 (2)</td>
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<td>Side of injection</td>
<td>0 (0)</td>
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<td>Antecubital vein used</td>
<td>15 (31)</td>
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<td>Postprocessing parameter</td>
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<tr>
<td>Use of deconvolution</td>
<td>31/49 (63)</td>
<td>18/49 (37)</td>
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<tr>
<td>Arterial input function selection laterisation*</td>
<td>19/31 (61)</td>
<td>12/31 (29)</td>
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<td>23/31 (74)</td>
<td>8/31 (26)</td>
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<td>Venous output function site</td>
<td>10/20 (50)</td>
<td>10/20 (50)</td>
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*MR indicates magnetic resonance; CT, computed tomography; TE, echo time; TR, repetition time; Kv, kilovoltage; sSVD, standard singular value decomposition; SVD, singular value decomposition; ICA, internal carotid artery; MCA, middle cerebral artery; ACA, anterior cerebral artery.

The upper section compares study acquisition parameters to the roadmap.

The lower section presents data for postprocessing parameters.

Proportions are those of MR papers which used deconvolution.
performed to an agreed standard, even if some acquisition parameters are deliberately omitted. Improved homogeneity of acquisition parameters may aid clinical trial conduct as well as translation to clinical practice.

Limitations of this study include focused coverage of the literature and the use of a consensus statement (the Roadmap) as a reference standard. In addition, practice may have changed since the analysis.

In conclusion, although word space is limited in journals, many details could easily be provided in an online version. Perhaps a “standard for reporting perfusion imaging” (STRPI) could be implemented following consensus on the EQUATOR Network and by journal editors.

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Disclosures
None.

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- Olivot Stroke 2009 40 * 469
- Zaro-Weber Stroke 2009 40 * 2413

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