Reliability of Measuring Lesion Volumes in Transient Ischemic Attack and Minor Stroke

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Background and Purpose—Lesion volume measurements in disabling ischemic stroke have excellent reliability, but it is not clear whether this is also true for small lesions. We assessed the reliability of measuring baseline and follow-up lesion volumes in transient ischemic attack and minor stroke.

Methods—Patients who presented with a transient ischemic attack or minor stroke (NIHSS ≤3) who had brain MRI within 24 hours from symptom onset and at 30-day follow-up and had an acute lesion on baseline MRI were included. Using semiautomated software, 4 stroke fellows independently assessed ischemic lesions twice on acute diffusion-weighted imaging and follow-up fluid-attenuated inversion recovery.

Results—Eighty patients were included, with a median baseline NIHSS of 1. Mean baseline diffusion-weighted imaging lesion volume was 3.4 ± 7.4 mL (87.5% had <5 mL). There was excellent inter-rater/intrarater reliability, with intraclass correlation coefficients of 0.94/0.96 for acute diffusion-weighted imaging, 0.74/0.92 for follow-up fluid-attenuated inversion recovery, and 0.81/0.93 for growth.

Conclusion—We found excellent concordance between and within raters for acute diffusion-weighted imaging and 30-day follow-up fluid-attenuated inversion recovery lesion volume measurements in patients with transient ischemic attack and minor stroke. (Stroke. 2010;41:814-816.)

Key Words: stroke ■ transient ischemic attack ■ volume measurement

Diffusion-weighted imaging (DWI) of acute ischemic lesion volumes correlate with clinical severity and outcome. Fluid-attenuated inversion recovery (FLAIR) sequences can be used to visualize infarction in the chronic stages. Intrarater and inter-rater concordance is excellent for acute DWI and chronic FLAIR lesion volumes in stroke patients. However, a relatively large margin of error for measurement of small lesions (<5 mL) has been reported. This study investigated the reliability of volume measurements in minor stroke and transient ischemic attack (TIA) patients on acute DWI, final infarct volume on 30-day FLAIR, and infarct growth.

Materials and Methods

Imaging data were from a prospective cohort study (The VISION study), which was approved by the institutional ethics committee. Patients older than 18 years with a premorbid modified Rankin Scale score <2 with minor stroke (NIHSS ≤3) or TIA (motor or speech symptoms lasting ≥5 minutes) examined by a stroke neurologist within 12 hours from symptom onset were eligible for this study. Patients who received thrombolytic therapy were excluded.

Imaging

Baseline MRI, including DWI, apparent diffusion coefficient, and FLAIR imaging, was performed within 24 hours of symptom onset using a 3-Tesla scanner. Follow-up MRI was completed at 30 days from symptom onset. Four board-certified neurologists (or equivalent) who were completing a stroke fellowship, blinded to all clinical data, assessed lesion volume. Each rater repeated all measurements several weeks after the first reading. Acute and chronic ischemic lesion volumes were detected by baseline DWI hyperintensity/apparent diffusion coefficient hypointensity and 30-day follow-up FLAIR. To distinguish new from old lesions, readers were allowed to compare to baseline sequences when measuring follow-up FLAIR volumes. New lesions distant from the baseline lesion were not included in the final lesion volume. Hemorrhagic conversion was included if hemorrhage was involved in an area of infarction. Measurements were aided by a semiautomated custom software (QUANTOMO) that utilized threshold-based region growing algorithms for computer-assisted volumetric analysis. Final lesion boundaries and volumes were defined by the rater (Figure 1).

Statistics

Reliability of measuring DWI (acute MRI), FLAIR (30-day MRI), and infarct growth volumes between and within raters were evaluated by the intraclass correlation coefficient (ICC). Infarct growth...
was defined as the difference between 30-day FLAIR and baseline DWI lesion volumes. Values of ICC >0.8 are considered to represent near-perfect agreement.

Results
Eighty patients met inclusion criteria for this reliability study. Average age was 68±11 years and 41.3% were male. Median baseline NIHSS was 1. Mean time from symptom onset to baseline MRI was 10.4±6.3 hours.

The mean volume of baseline DWI lesions was 3.4±7.4 mL, with the majority of patients (87.5% of 80) having acute DWI lesions <5 mL. Inter-rater and intrarater reliability were excellent (ICC, 0.94/0.96; lower 95% CI, 0.88/0.86), as shown in Figure 2 and the Table. Mean volume of follow-up FLAIR lesions was 6.4±13.3 mL. Interrater reliability was good (ICC, 0.74; lower 95% CI, 0.68). Intrarater reliability was excellent (ICC, 0.92; lower CI, 0.88). Mean growth was 2.9±12.2 mL. Inter-rater and intrarater reliability were excellent (ICC, 0.81/0.93; lower CI, 0.77/0.90).

Discussion
Inter-rater and intrarater reliability for measurement of acute DWI and 30-day follow-up FLAIR lesion volume as well as infarct growth in patients with TIA or minor stroke (NIHSS ≤3) were good to excellent. Inter-rater and intrarater concordances for measurement of ischemic lesion volumes (acute DWI and mean transit time, chronic FLAIR) in patients with stroke of any clinical severity are good with inaccuracies predominantly in small DWI lesions. A minimum of 5 mL restricted diffusion on acute MRI has been proposed for image-based stroke trial patient selection. However, TIA and minor stroke are the focus of intense research involving acute MRI imaging and volume measurement without adequate reliability data. As expected, the average volume of the acute lesions was small, with a mean of 3.4 mL (87.5% of patients had <5 mL).

Abnormalities on MRI sequences frequently overlap with nonpathological structures. Therefore, rater judgment was
needed in each particular case to correctly define the lesions. Thus, differences between the readers are attributable to individual interpretation of subtle changes, inclusion or exclusion of sulcal areas, encephalomalacia, or hematoma.

**Conclusion**

In conclusion, this study shows excellent concordance within and between raters for acute DWI and 30-day follow-up FLAIR lesion volume measurement in patients with TIA and minor stroke. In particular, this holds true when including patients with small acute lesions (<5 mL). Reliable volume measurement as an objective quantitative tool may be relevant to future stroke trial design and lesion analysis.

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**Disclosures**

None.

**References**


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**Table. Inter-Rater and Intrarater Volume Statistics for Acute DWI, Follow-Up FLAIR, and Growth**

<table>
<thead>
<tr>
<th></th>
<th>Volumes, mL</th>
<th>Interrater</th>
<th>Intrarater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Median</td>
</tr>
<tr>
<td>Acute DWI</td>
<td>3.4</td>
<td>7.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Follow-up FLAIR</td>
<td>6.4</td>
<td>13.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Growth</td>
<td>2.9</td>
<td>12.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>

IQR indicates interquartile range; LCI, lower confidence interval.
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