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

Nikolai Steffenhagen, MD; Cynthia R. Campos, MD; Alexandre Y. Poppe, MD, FRCPC; Firosh Khan, MD; Jayme C. Kosior, BSc; Andrew M. Demchuk, MD, FRCPC; Michael D. Hill, MD, FRCPC; Shelagh B. Coutts, MD, FRCPC

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.

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.

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 $\geq 0.8$ 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 $\leq$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

**Figure 1.** Volume measurement of right hemispheric ischemic lesions on acute DWI using semiautomated software. First row, Plain images. Second row, Rough circumscription (red) of ischemic lesions after placing curser into right hemispheric hyperintensities to define regions of interest (ROI) and setting an upper (highest intensity measured within ROI) and lower threshold (intensity of unaffected white matter). Unaffected tissue adjacent to lesion is involved in volume measurement. Third row, Approximation of true DWI hyperintensity/lesion by adjusting threshold parameters as judged by individual rater based on plain images. Volume of lesion calculated and presented by software according to circumscribed area (red) and slice thickness.

**Figure 2.** Relationship between individual reader score and mean DWI volume score. The line is a line of best fit and also a line of unity for comparison. Each open data point represents 1 score from each of 4 readers (triangle, square, diamond, circle).
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.

Sources of Funding

This study was supported by grant funding from the Canadian Institutes for Health Research (MOP-118096) and Heart and Stroke Foundation of Alberta, NWT and Nunavut. The 3.0 T MR Scanner in the Seaman Family MR Research Centre used in this study was partially funded by Canada Foundation for Innovation. Acute stroke imaging was also supported by the Alberta Foundation for Health Research. Drs Coutts, Demchuk and Hill received salary support from the Alberta Heritage Foundation for Medical Research. Dr Coutts was supported by the Heart and Stroke Foundation of Canada Distinguished Clinician Scientist award, supported in partnership with the CIHR Institute of Circulatory and Respiratory Health and AstraZeneca Canada Inc.

Disclosures

None.

References


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

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

IQR indicates interquartile range; LCI, lower confidence interval.
Reliability of Measuring Lesion Volumes in Transient Ischemic Attack and Minor Stroke
Nikolai Steffenhagen, Cynthia R. Campos, Alexandre Y. Poppe, Firosh Khan, Jayme C. Kosior, Andrew M. Demchuk, Michael D. Hill and Shelagh B. Coutts

Stroke. 2010;41:814-816; originally published online February 11, 2010;
doi: 10.1161/STROKEAHA.109.570358
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2010 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/41/4/814

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org/subscriptions/