Planimetric Hematoma Measurement in Patients With Intraventricular Hemorrhage

Is Total Volume a Preferred Target for Reliable Analysis?

Dar Dowlatshahi, MD, PhD; Jayne C. Kosior, PhD; Sherif Idris, MD; Muneer Eesa, MD; Peter Dickhoff, MD; Manish Joshi, MD, PhD; Suresh Subramaniam, MD; Sarah Tymchuk, BSc; Michael D. Hill, MD, MSc; Richard I. Aviv, MD; Richard Frayne, PhD; Andrew M. Demchuk, MD; on behalf of the PREDICT/Sunnybrook ICH-CTA study group

Background and Purpose—Reliable quantification of both intracerebral hemorrhage and intraventricular hemorrhage (IVH) volume is important for hemostatic trials. We evaluated the reliability of computer-assisted planimetric volume measurements of IVH.

Methods—Computer-assisted planimetry was used to quantify IVH volume. Five raters measured IVH volumes, total (intracerebral hemorrhage+IVH) volumes, and Graeb scores from 20 randomly selected computed tomography scans twice. Estimates of interrater and intrarater reliability were calculated and expressed as an intrarater correlation coefficient and an absolute minimum detectable difference.

Results—Planimetric IVH volume analysis had excellent intra- and interrater agreement (intrarater correlation coefficient, 0.96 and 0.92, respectively), which was superior to the Graeb score (intrarater correlation coefficient, 0.88 and 0.83). Minimum detectable differences for intra- and interrater volumes were 12.1 mL and 17.3 mL, and were dependent on the total size of the hematoma; hematomas smaller than the median 43.8 mL had lower minimum detectable differences, whereas those larger than the median had higher minimum detectable differences. Planimetric total hemorrhage volume analysis had the best intra- and interrater agreement (intrarater correlation coefficient, 0.99 and 0.97, respectively).

Conclusions—Computer-assisted planimetric techniques provide a reliable measurement of ventricular hematoma volume, but are susceptible to higher absolute error when assessing larger hematomas. (Stroke. 2012;43:00-00.)

Key Words: intracerebral hemorrhage intraventricular hemorrhage planimetry

Hematoma volume and intraventricular hemorrhage (IVH) are independent predictors of outcome following intracerebral hemorrhage (ICH).1–2 Early ventricular rupture and subsequent autodecompression of parenchymal hematoma is common in ICH.3 Ventricular decompression of ICH results in IVH expansion, which is also associated with poor outcome.2 Given that hematoma expansion is a common surrogate outcome for ICH studies,3 easy and accurate measurement of IVH and volume dynamics following ventricular rupture is relevant to hemostatic trials. In this study, we sought to evaluate the reliability of computer-assisted planimetric measurements for quantifying IVH volumes.

Methods

The computer-assisted volume measurement software Quantomo (Cybertrial)5 was used to quantify IVH volumes. Quantomo provides an interface that enables raters to guide segmentation algorithms with manual planimetric intervention to quantify volumes on computed tomography (CT) and magnetic resonance scans. Raters measured ICH and IVH volumes by selecting a hematoma and adjusting intensity thresholds, adding or removing regions to the computer-selected region at their discretion, and manually drawing boundaries to separate IVH from ICH. CT scans of patients with both ICH and IVH were blindly and randomly selected from the ongoing PREDICT study.6 Five raters (2 neurologists, 1 radiologist, 1 neuroradiologist, and 1 radiology trainee) measured IVH volumes, total (ICH+IVH) volumes, and Graeb scores from 20 randomly selected CT scans twice, presented in a blinded, random fashion over 2 reading sessions, separated by a minimum of 7 days. Estimates of interrater and intrarater reliability were calculated using a 2-way random-effects ANOVA, and expressed as an intrarater correlation coefficient (ICC).7 The minimum detectable difference (MDD) for IVH and total volumes was determined. To assess how hematoma size affects MDD, we performed a post hoc

Received February 23, 2012; accepted March 19, 2012.

From the Department of Medicine (D.D.), University of Ottawa & Ottawa Hospital Research Institute, Ottawa, Canada; Department of Electrical and Computer Engineering (J.C.K., R.F.); Seaman Family MR Research Centre (J.C.K., S.I., M.E., S.S., M.J., M.D.H., R.F., A.M.D.), Foothills Medical Centre, Calgary, Canada; Hotchkiss Brain Institute (J.C.K., M.E., M.D.H., R.F., A.M.D.), Department of Clinical Neurosciences (S.S., M.D.H., R.F., A.M.D.), Department of Radiology (M.E., P.D., M.J., M.D.H., R.F., A.M.D.), Department of Medicine (M.D.H.), Department of Community Health Sciences (M.D.H.), University of Calgary, Calgary, Canada; Department of Medical Imaging (R.I.A.), University of Toronto, Division of Neuroradiology, Sunnybrook Health Sciences Center, Toronto, Canada.

Correspondence to Dar Dowlatshahi, MD, PhD, FRCP, Division of Neurology, Department of Medicine, Ottawa Hospital Civic Campus, Room C2182b, 1053 Carling Ave, Ottawa, Ontario, Canada. E-mail ddowlat@toh.on.ca

© 2012 American Heart Association, Inc.

Stroke is available at http://stroke.ahajournals.org

DOl: 10.1161/STROKEAHA.112.654970
Table 1. Intrarater Correlation Coefficients for Quantomo and the Commonly Used Graeb Score. Minimal Detectable Difference for Quantomo is Shown, But Cannot Be Calculated for Categorical Scales

<table>
<thead>
<tr>
<th></th>
<th>Intrarater</th>
<th></th>
<th>Interrater</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (ml)</td>
<td>MDD (ml)</td>
<td>ICC (ml)</td>
<td>MDD (ml)</td>
</tr>
<tr>
<td>Graeb</td>
<td>0.88</td>
<td>...</td>
<td>0.83</td>
<td>...</td>
</tr>
<tr>
<td>Quantomo IVH</td>
<td>0.96</td>
<td>12.1</td>
<td>0.92</td>
<td>17.3</td>
</tr>
<tr>
<td>Quantomo total</td>
<td>0.99</td>
<td>11.3</td>
<td>0.97</td>
<td>18</td>
</tr>
</tbody>
</table>

ICC indicates intrarater correlation coefficient; MDD, minimal detectable difference; IVH, intraventricular hemorrhage.

Results

Median total hematoma volume was 43.8 mL (interquartile range, 50.8 mL). Quantomo IVH and total volume analyses had excellent intra- and interrater agreements, which were superior to the Graeb score (Table 1). Intrarater ICC was 0.96 (95% lower CI, 0.91) and interrater ICC was 0.92 (95% lower CI, 0.87). MDD estimates were found in post hoc analysis to be dependent on the total size of the hematoma: hematomas smaller than the median had lower MDDs, whereas those larger had higher MDDs (Table 2). Larger hematomas were frequently associated with distortion of anatomic landmarks and unclear boundaries between parenchymal and ventricular hematoma; interrater discrepancies were increased in these scans (Figure 1).

Discussion

Parenchymal hematoma volume, early hematoma expansion, and presence of ventricular hemorrhage are important predictors of poor outcomes in ICH.1–3 Decompression of parenchymal hematoma into the ventricular space, and ventricular hemorrhage expansion are also associated with worse outcomes.2,3 In this study, we report that planimetric volume measurements have excellent ICCs for assessing IVH volume expansion, and compare favorably with the commonly used Graeb score.

The validity of computer-assisted planimetry for parenchymal ICH volumetric analysis was previously reported.5 In the current study, we report ICCs for IVH measurements and present the MDDs for both IVH and total hematoma measurements. The commonly used Graeb score and the new IVH score6 are effective for prognostication and for rapidly estimating IVH volume. However, these categorical scales were not designed to measure accurately hematoma expansion in trials of hemostasis or blood pressure reduction. We propose that planimetry is preferable in this context, particularly when hemorrhage expansion is used as surrogate outcome in trials. However, the higher MDD associated with larger hematomas should be taken into account when choosing volumetric outcomes in ICH expansion trials.

A strength of this study was that we reported the MDD for IVH measurements; we feel this parameter is crucial for trials of hematoma expansion, because dichotomous growth definitions chosen for a given trial must be greater than their MDD. Larger hematomas are more likely to distort anatomic landmarks and obscure boundaries between parenchymal and ventricular blood, which may worsen ICC and MDD (Figure 1). Our limited sample size precluded detailed assessment of the relationship between hematoma size and measurement precision; a much larger sample of patients will be required to address this.

When interpreting our results, a distinction should be made between MDD and the minimally important difference.9 The MDD reported in this study is a reflection of the absolute error of measurement, and not necessarily related to a relevant clinical outcome. The minimally important difference for hematoma expansion reflects the amount of growth required to predict reliably a negative clinical outcome, and is beyond the scope of the current study. Although we recently reported the relationship between parenchymal hematoma expansion definitions and clinical outcomes following ICH,10 the minimally important difference for ventricular expansion is not yet known. To be a useful measurement technique, the MDD of ICH measurement should be lower than the minimally important difference for hematoma expansion.

Table 2. MDD Were Lower for Hematomas Smaller Than the Median (Top) Compared With Those Larger Than the Median (Bottom)

<table>
<thead>
<tr>
<th></th>
<th>Intrarater</th>
<th></th>
<th>Interrater</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (ml)</td>
<td>MDD (ml)</td>
<td>ICC (ml)</td>
<td>MDD (ml)</td>
</tr>
<tr>
<td>Total Hematoma Volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤34 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantomo IVH</td>
<td>0.89</td>
<td>7.7</td>
<td>0.82</td>
<td>10</td>
</tr>
<tr>
<td>Quantomo total</td>
<td>0.96</td>
<td>6.1</td>
<td>0.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Total Hematoma Volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;34 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantomo IVH</td>
<td>0.96</td>
<td>15.3</td>
<td>0.91</td>
<td>22.3</td>
</tr>
<tr>
<td>Quantomo total</td>
<td>0.98</td>
<td>14.8</td>
<td>0.95</td>
<td>23.7</td>
</tr>
</tbody>
</table>

ICC indicates intrarater correlation coefficient; MDD, minimal detectable difference; IVH, intraventricular hemorrhage.

Acknowledgments

We thank the PREDICT/Sunnybrook ICH-CTA Study Group investigators for contributing patients that were included in this analysis.

Sources of Funding

D.D. was supported by the Canadian Institutes of Health Research. J.C.K. was supported by the Alberta Heritage Foundation for Medical Research, Informatics Circle of Research Excellence, and the National Science and Engineering Research Council. R.F. is the Hopewell Professor of Brain Imaging and a Canada Research Chair. A.M.D. is an Alberta Innovates Health Solutions Scholar and Heart & Stroke Foundation Chair in Stroke Research. M.D.H. has been funded by Heart & Stroke Foundation of Alberta/NWT/NU and by Alberta Innovates Health Solutions. The PREDICT study was
funded by an unrestricted grant from NovoNordisk Canada and Canadian Stroke Consortium.

Disclosures

References
Planimetric Hematoma Measurement in Patients With Intraventricular Hemorrhage: Is Total Volume a Preferred Target for Reliable Analysis?
Dar Dowlatshahi, Jayme C. Kosior, Sherif Idris, Muneer Eesa, Peter Dickhoff, Manish Joshi, Suresh Subramaniam, Sarah Tymchuk, Michael D. Hill, Richard I. Aviv, Richard Frayne and Andrew M. Demchuk
on behalf of the PREDICT/Sunnybrook ICH-CTA study group

*Stroke*. published online May 15, 2012;

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 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/early/2012/05/15/STROKEAHA.112.654970

**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/