Planimetric Hematoma Measurement in Patients With Intraventricular Hemorrhage
Is Total Volume a Preferred Target for Reliable Analysis?

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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;43:1961-1963.)

Key Words: intracerebral hemorrhage ■ intraventricular hemorrhage ■ planimetry

Hematoma volume and intraventricular hemorrhage (IVH) are independent predictors of outcome following intracerebral hemorrhage (ICH). Early ventricular rupture and subsequent autodecompression of parenchymal hematoma is common in ICH. Ventricular decompression of ICH results in IVH expansion, which is also associated with poor outcome. Given that hematoma expansion is a common surrogate outcome for ICH studies, 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) 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. 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). The minimum detectable difference (MDD) for IVH and total volumes was determined. To assess how hematoma size affects MDD, we performed a post hoc
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>Interrater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>MDD (ml)</td>
</tr>
<tr>
<td>Graeb</td>
<td>0.88</td>
<td>. .</td>
</tr>
<tr>
<td>Quantomo IVH</td>
<td>0.96</td>
<td>12.1</td>
</tr>
<tr>
<td>Quantomo total</td>
<td>0.99</td>
<td>11.3</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. Decompression of parenchymal hematoma into the ventricular space, and ventricular hemorrhage expansion are also associated with worse outcomes. In this study, we report that planimetric volume measurements have excellent ICCs for assessing IVH volume and expansion, and compare favorably with the commonly used Graeb score.

The validity of computer-assisted planimetry for parenchymal ICH volumetric analysis was previously reported. 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 score 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. 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, 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>Total Hematoma Volume</th>
<th>Intrarater</th>
<th>Interrater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>MDD (ml)</td>
</tr>
<tr>
<td>≤43 mL</td>
<td>0.89</td>
<td>7.7</td>
</tr>
<tr>
<td>Quantomo IVH</td>
<td>0.96</td>
<td>6.1</td>
</tr>
<tr>
<td>Quantomo total</td>
<td>0.96</td>
<td>15.3</td>
</tr>
<tr>
<td>&gt;43 mL</td>
<td>0.98</td>
<td>14.8</td>
</tr>
</tbody>
</table>

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

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Disclosures

References

Figure. A, The purple areas on this CT represent regions selected as intraparenchymal hematoma by 2 different readers; despite good interrater agreement for total hematoma volume and Graeb score, the lack of clear boundary between ICH and IVH contributed to disagreement in IVH measurement. B, A large hematoma with mass effect, shift, and hydrocephalus. The red and blue regions represent IVH as identified by 2 different readers, demonstrating the interrater variability resulting from distortion of anatomic landmarks.
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