Intracerebral hematoma (ICH) is a significant cause of death and disability worldwide. The volume of ICH has been validated to be an important independent predictor for prognosis. The Tada (ABC/2) formula has been used widely for bedside estimation of hematoma volume, assuming that hematoma shape is idealized ellipsoid. Clinically, hematoma shape is often irregular rather than ellipsoid. It is therefore reasonable to assume that the ABC/2 formula has a certain range of error, which, theoretically, will be larger in irregular or larger hematomas.

3D Slicer is a free open source software platform for biomedical research (http://www.slicer.org). It is similar to a radiology workstation but is free and not tied to specific hardware. 3D Slicer not only supports versatile visualizations but also provides advanced function, such as automated segmentation and registration for various applications.

In this study, we aimed to validate the size-dependent and shape-dependent estimation error of the ABC/2 formula by comparison with 3D Slicer.

Materials and Methods

Patients
For this study, we enrolled patients admitted to our hospital between January 2009 and June 2013 with diagnosis of spontaneous ICH.
group 3 contained 94 patients with volume >60 cm³. Shape of the hematoma was divided (on the basis of the maximal slice) into regular (round to ellipsoid) with smooth margins (169 cases); irregular with frayed margins (97 cases); and multilobular (28 cases).

Statistical Analysis
All statistical analyses were performed with SPSS statistics 21 (IBM Corporation, America). After confirmation of distribution, data are expressed as mean±SD and unpaired \(t\)-test or 1-way ANOVA was used for comparison between different techniques and groups as appropriate. A value of \(P<0.05\) was considered statistically significant.

Results
The mean hematoma volume was 58.41±37.83 cm³ with the ABC/2 formula and 50.38±31.93 cm³ with 3D Slicer method.

| Table. Hematoma Volumes Measured by Different Methods |
|----------------------------------|------------------|--------------|--------------|
| Groups                          | Hematoma Volume, cm³ | Deviation (%) |
| General volume                  | 3D Slicer | ABC/2      | 3D Slicer | ABC/2     | 3D Slicer | ABC/2     | 3D Slicer | ABC/2     | 3D Slicer | ABC/2     | 3D Slicer | ABC/2     |
| Size*                           |          |            |            |          |            |            |          |            |            |          |            |            |
| Group 1 (n=89)                  | 38.03±11.25 | 41.36±13.85 | 9.76±7.42  | 38.03±11.25 | 41.36±13.85 | 9.76±7.42  | 38.03±11.25 | 41.36±13.85 | 9.76±7.42  | 38.03±11.25 | 41.36±13.85 | 9.76±7.42  |
| Group 2 (n=111)                 | 52.58±15.82 | 59.77±18.47 | 18.37±11.99 | 52.58±15.82 | 59.77±18.47 | 18.37±11.99 | 52.58±15.82 | 59.77±18.47 | 18.37±11.99 | 52.58±15.82 | 59.77±18.47 | 18.37±11.99 |

*Group 1: <30 cm³; group 2: 30 to 60 cm³; and group 3: >60 cm³.

When dividing patients into groups based on hematoma size, the ABC/2 formula produced a significant estimation error of 3.33, 7.19, and 29.39 cm³ in regular, irregular, and multilobular hematomas (\(P<0.05\) in each group). The mean percentage deviations of the ABC/2 formula from 3D Slicer were 17.72±8.55%, 13.72±7.86%, and 17.48±9.28%, respectively (Figure 2). There were no significant difference for the percent deviation among these three groups (\(H=4.537; \ P>0.05\)).

When divided by hematoma shape, the ABC/2 formula produced a significant estimation error of 3.33, 7.19, and 29.39 cm³ in regular, irregular, and multilobular hematomas (\(P<0.05\) in each group). The mean percentage deviations of the ABC/2 formula from 3D Slicer were 17.72±8.55%, 13.72±7.86%, and 17.48±9.28%, respectively (Figure 2). The percent deviation was significantly larger in irregular and multilobular hematomas compared with regular hematomas (\(H=63.052; \ P<0.001\)).

Discussion
Accurate measurement of hematoma volume is clinically important because hematoma volume has been used widely to correlate with treatment strategy, functional outcome, and...
mortality. An inaccurately assessed hematoma volume would inevitably influence initial treatment decisions, resulting in an undesirable outcome. Precise hematoma volume assessment is also critical for clinical trials, in which hematoma volume change may be a surrogate end point.

In this study, the ABC/2 formula demonstrated an overall 8.03 cm³ (16.38%) estimation error compared with 3D Slicer method. When grouping by hematoma size, percent deviation had no significant difference. Possibly, estimation error increased with hematoma volume at a similar speed. But when grouping by hematoma shape, percent deviation was significantly different. Estimation error was more common and of greater magnitude when hematoma shape was irregular or multilobular. Compared with hematoma size, estimation error of the ABC/2 formula correlated more with hematoma shape.

Our results were also supported by previously published literatures. Huttner et al demonstrated that the ABC/2 formula accurately and quickly calculates volumes of small, ellipsoid intraparenchymal hematomas, but underestimates larger, complex-shaped, and warfarin-associated intraparenchymal hematomas. Divani et al also demonstrated increased error when measuring irregularly shaped hematomas. Wang et al concluded that inaccuracies increase with hematoma size.

In this study, we measured hematoma volume with the free, open source software 3D Slicer, which could count all pixels compromising the hematoma semiautomatically without any assumption beyond the shape of hematoma. The average time it took for segmentation was only 96 seconds, which was relatively faster compared with traditional planimetric method. The accuracy of this software has been demonstrated in calculation of tumors. 3D Slicer has been shown to be faster and less user-intensive compared with manual delineation.

In conclusion, there is significant estimation error using the ABC/2 formula to calculate hematoma volume, especially for irregular and multilobular hematomas. Hematoma assessment with software 3D Slicer is a low-cost, accurate, and helpful technique for measurement of ICH volume.

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Disclosures
None.

References
Comparison of the Tada Formula With Software Slicer: Precise and Low-Cost Method for Volume Assessment of Intracerebral Hematoma
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