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

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Background and Purpose—The Tada (ABC/2) formula has been used widely for volume assessment of intracerebral hematoma. However, the formula is crude for irregularly shaped hematoma. We aimed to compare the accuracy of the ABC/2 formula with open source software Slicer.

Methods—Computed tomographic images of 294 patients with spontaneous intracerebral hematoma were collected. Hematoma volumes were assessed with the ABC/2 formula and calculated with software 3D Slicer. Results of these 2 methods were compared with regard to hematoma size and shape.

Results—The estimated hematoma volume was 58.41±37.83 cm³ using the ABC/2 formula, compared with 50.38±31.93 cm³ with 3D Slicer (mean percentage deviation, 16.38±9.15%). When allocate patients into groups according to hematoma size, the mean estimation error were 3.24 cm³ (17.72%), 5.85 cm³ (13.72%), and 15.14 cm³ (17.48%) for groups 1, 2, and 3, respectively. When divided by shape, estimation error was 3.33 cm³ (9.76%), 7.19 cm³ (18.37%), and 29.39 cm³ (39.12%) for regular, irregular, and multilobular hematomas.

Conclusions—There is significant estimation error using the ABC/2 formula to calculate hematoma volume. Compared with hematoma size, estimation error is more significantly associated with hematoma shape. (Stroke. 2014;45:3433-3435.)

Key Words: hematoma volume ■ intracerebral hemorrhage ■ software ■ Tada formula

Intracerebral hematoma (ICH) is a significant cause of death and disability worldwide.¹ The volume of ICH has been validated to be an important independent predictor for prognosis.²⁻⁴ The Tada (ABC/2) formula has been used widely for bedside estimation of hematoma volume,⁵ 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.⁶

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.

Patients with simple intraventricular hemorrhage, intratumoral hemorrhage, traumatic hemorrhage, arteriovenous malformation, epidural or subdural hematomas, and multiple sites of ICH were excluded. Finally, 294 consecutive patients were enrolled. Our study was approved by the local ethical committee.

Imaging
A total of 294 brain computed tomographic image data sets were acquired in Digital Imaging and Communications in Medicine format. Shape categorization and volume estimation were all performed independently by 2 physicians. Hematoma volume used for analysis was averaged over both single values.

In the ABC/2 formula study group, the maximal length (A), width (B), and height (C) of the hematoma were measured on the viewer of the Picture Archiving and Communication System. In 3D Slicer method group, the Digital Imaging and Communications in Medicine data were transferred to a standard personal computer (Intel Core i3 CPU, 2×2.26GHz, 4GB RAM) and then assessed with 3D Slicer. Hematoma was automatically identified pixel by pixel in each slice after setting thresholds range at 50 to 100 HU. Then a three-dimensional model was constructed and the volume was given by accumulating volume of all the pixels (Figure 1).

Patient Groups
Patients were divided into 3 groups based on the hematoma size by 3D Slicer method: group 1 contained 89 patients with volume <30 cm³; group 2 contained 111 patients with volume of 30 to 60 cm³; and...
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. The mean percent deviation between both techniques was 16.38±9.15%. The Table shows the measured volumes for both techniques with respect to hematoma size and shape. The average time it took using 3D Slicer was 96 seconds.

When dividing patients into groups based on hematoma size, the ABC/2 formula produced a significant estimation error of 3.24, 5.85, and 15.14 cm³ for groups 1, 2, and 3, respectively (*P*<0.05 in each group). The mean percent deviation 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

![Figure 1](http://stroke.ahajournals.org/)

Figure 1. Hematoma was automatically identified and then 3-dimensionally reconstructed. Hematoma volume assessment with 3D Slicer. Various shapes of hematoma and examples of 3D Slicer processed models: (A) regular, (B) irregular, and (C) multilobular.

![Figure 2](http://stroke.ahajournals.org/)

Figure 2. Comparison of percent deviation between different groups using 1-way ANOVA. The box plot shows the upper and lower quartiles, median, and extremums. The analysis of percent deviation according to hematoma volume (A) and hematoma shape (B). Group 1: <30 cm³ and group 2: 30 to 60 cm³; and group 3: >60 cm³.
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.

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