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ARTICLE

The ABCs of Measuring Intracerebral Hemorrhage Volumes

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ABSTRACT: *Background and Purpose* Hemorrhage volume is a powerful predictor of 30-day mortality after spontaneous intracerebral hemorrhage (ICH). We compared a bedside method of measuring CT ICH volume with measurements made by computer-assisted planimetric image analysis.*Methods* The formula *ABC*/2 was used, where *A* is the greatest hemorrhage diameter by CT, *B* is the diameter 90° to *A*, and *C* is the approximate number of CT slices with hemorrhage multiplied by the slice thickness.*Results* The ICH volumes for 118 patients were evaluated in a mean of 38 seconds and correlated with planimetric measurements (R^2=.96). Interrater and intrarater reliability were excellent, with an intraclass correlation of .99 for both.*Conclusions* We conclude that ICH volume can be accurately estimated in less than 1 minute with the simple formula *ABC*/2.

Key Words: blood volume ■ computed tomography ■ intracerebral hemorrhage

The 30-day mortality rate of intracerebral hemorrhage (ICH) is approximately 44%, with almost half of the patients dying within the first 48 hours.[1] There is no proven effective treatment, and the ability to rapidly determine a patient's prognosis at the bedside would be a powerful tool in selecting and stratifying patients in future trials of surgical intervention. Hemorrhage volume, level of consciousness, and the presence of intraventricular extension have all been documented as predictors of ICH outcome.[2] The latter two can be easily evaluated. We compare a bedside method of ICH volume measurement[3] with a computerized planimetric measurement.

SUBJECTS AND METHODS

One hundred eighteen patients with spontaneous ICH were assessed prospectively with CT within 3 hours of symptom onset. Exclusion criteria included (1) CT evidence of a subarachnoid hemorrhage, (2) history of recent trauma, (3) isolated

intraventricular hemorrhage, and (4) ICH due to aneurysm or arteriovenous malformation. Hemorrhage volumes were measured by a computerized planimetric method and a simplified formula for the volume of an ellipsoid, *ABC*/2 (see "Appendix"). Measurement by planimetrics is an established and accurate method of measuring ICH volume that uses computer-assisted image analysis.[2 4 5]

For the bedside *ABC*/2 method, the CT slice with the largest area of hemorrhage was identified. The largest diameter *(A)* of the hemorrhage on this slice was measured. The largest diameter 90° to *A* on the same slice was measured next *(B)*. Finally, the approximate number of 10-mm slices on which the ICH was seen was calculated *(C)*. *C* was calculated by a comparison of each CT slice with hemorrhage to the CT slice with the largest hemorrhage on that scan. If the hemorrhage area for a particular slice was greater than 75% of the area seen on the slice where the hemorrhage was largest, the slice was considered 1 hemorrhage slice for determining *C*. If the area was approximately 25% to 75% of the area, the slice was considered half a hemorrhage slice; and if the area was less than 25% of the largest hemorrhage, the slice was not considered a hemorrhage slice. These CT hemorrhage slice values were then added to determine the value for *C*. All measurements for *A* and *B* were made with the use of the centimeter scale on the CT scan to the nearest 0.5 cm. *A, B,* and *C* were then multiplied and the product divided by 2, which yielded the volume of hemorrhage in cubic centimeters. The time required for the measurements and calculations was recorded. Hemorrhage volumes determined by the two techniques were then compared by regression analysis.

Twenty CT scans were randomly selected from the study population of 118, and hemorrhage volumes were measured by four individuals (a neurosurgery faculty member [M.Z.], a third-year neurosurgery resident, an emergency medicine faculty member [R.U.K], and a registered nurse [L.R.S.]) with the *ABC*/2 technique.

We evaluated intrarater reliability for a single reader by comparing initial measurements of these 20 CT scans using the *ABC*/2 method with repeated measurements by the same investigator using the same technique.

RESULTS

Of the 118 patients evaluated, 83 (70%) were deep hemorrhages, 21 (18%) were lobar, 8 (7%) were brain stem, and 6 (5%) were cerebellar. The correlation between measurements by planimetric and *ABC*/2 methods was very high (R^2=.96). Measurements by a single reader using the *ABC*/2 method correlated well with planimetric measurements for all hemorrhage locations (Table 1). The *ABC*/2 method overestimated hemorrhage volume by 1.5±1.3 cm^3. The *ABC*/2 method required a mean time of 38 seconds (range, 70 to 210 seconds). In the subset of 20 CT scans measured by four different readers, we noted excellent interrater (intraclass correlation=.99) and intrarater (intraclass correlation=.99) reliability when the *ABC*/2 technique was used (Table 2). The mean time per measurement for the readers ranged from 31 to 40 seconds.

DISCUSSION

A number of techniques have been developed to measure hemorrhage volume.[2 6 7 8] Unfortunately, these methods often involve complicated formulas, require specialized equipment, or cannot be performed rapidly at the patient's bedside. We found that the simple formula *ABC*/2 can accurately estimate intraparenchymal hemorrhage volume and requires less than 1 minute for measurement and calculation. The measurements correlate highly with the volumes calculated by planimetric methods for all hemorrhage locations.

Rapid calculation of ICH volume at the time of initial patient presentation has clinical utility. For prognosis, a model of 30-day mortality that used the Glasgow Coma Scale and hemorrhage volume in patients with ICH correctly predicted outcome with a sensitivity and specificity of 97%.[2] The *ABC*/2 technique may also be used to identify appropriate patients with ICH suitable for randomization into therapeutic trials.[3] For example, the technique is the measurement method used for patient eligibility assessment in the multicenter Surgical Trial of Intracerebral Hemorrhage (J. Grotta, unpublished data, 1996). In this trial, patients with ICH and anticipated good outcome are not eligible for surgery. Thus, patients with hemorrhage volumes of less than 10 cm^3 and patients with lobar hemorrhage volumes of 10 to 20 cm^3 with minimal or no neurological deficits are excluded.

The *ABC*/2 and other bedside techniques of calculating hemorrhage volumes have been described previously.[3 5 6] Lisk and colleagues[3] demonstrated the ease and power of the *ABC*/2 method of volume measurement in a model of outcome after ICH but did not correlate this technique with other methods of volume measurement. The *ABC*/2 formula can be adjusted for CT slices of varying thickness by multiplying the number of slices of the different thicknesses on which the hematoma is seen (*C* of *ABC*/2) by the slice thickness in centimeters. Other authors have estimated hematoma volume by assuming it to approximate the volume of a sphere, an ellipsoid, or a rectangulopiped.[2 7 8] Only estimates of volume that use the formula for an ellipsoid have been shown to correlate with planimetric techniques.[5]

In conclusion, intraparenchymal hemorrhage volume can be accurately estimated in less than 1 minute with the simple formula *ABC*/2. This rapid method of measuring hemorrhage volume may allow physicians to quickly select and stratify patients in future treatment trials.

APPENDIX

The derivation of the *ABC*/2 formula is as follows: The volume of an ellipsoid is $4/3\pi(A/2)(B/2)(C/2)$, where *A*, *B*, and *C* are the three diameters. If π is estimated to be 3, then the volume of an ellipsoid becomes *ABC*/2.

Table 1. Mean Hemorrhage Volumes (Table view)

		Hemorrhage Volume, cm^3		
Location	No.	Planimetric	*ABC*/2	R^2

		Hemorrhage Volume, cm^3		
Deep	83	23.0±2.7	23.5±2.9	.94
Lobar	21	44.6±8.4	49.9±9.9	.96
Brain stem	8	13.6±7.2	12.3±6.3	.99
Cerebellar	6	19.6±4.3	24.4±5.9	.78
Total	118	26.0±2.6	27.5±2.9	.96

Hemorrhage volumes are mean±SE.

Table 2. Reliability and Reproducibility of the *ABC*/2 Method of Measuring Intraparenchymal Hemorrhage Volume (Table view)

Reader	No.	Intraclass Correlation	Difference From Planimetric,* cm^3	*P*†	Mean Time per Measurement,‡ s
1 (Neurosurgery faculty)	20	.99	−2.0±1.2	.11	35
2 (Neurosurgery resident)	20	.99	0.6±3.0	.85	40
3 (Emergency physician)	20	.99	0.8±1.3	.55	33
4 (Nurse)	20	.99	−2.5±1.5	.07	31
Interrater reliability (readers 1-4):		Intraclass correlation=.99			
Intrarater reliability (reader 3):		Intraclass correlation=.99 (*P*=.19)			

*Mean±SE difference from planimetric measurement.
†Difference from planimetric measurement.
‡Mean time to determine hemorrhage volume per CT scan with the *ABC*/2 technique.

ARTICLE INFORMATION

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Note

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REFERENCES

1. Broderick J, Brott T, Tomsick T, Huster G, Miller R. The risk of subarachnoid and intracerebral hemorrhages in blacks as compared with whites. *N Engl J Med.* 1992;*326*:733-736. Crossref. PubMed.

2. Broderick, JP, Brott TG, Duldner JE, Tomsick T, Huster G. Volume of intracerebral hemorrhage: a powerful and easy-to-use predictor of 30-day mortality. *Stroke.* 1993;*24*:987-993. Crossref. PubMed.
3. Lisk DR, Pasteur W, Rhoades H, Putnam RD, Grotta JC. Early presentation of hemispheric intracerebral hemorrhage: prediction of outcome and guidelines for treatment allocation. *Neurology.* 1994;*44*:133-139. Crossref. PubMed.
4. Broderick JP, Brott TG, Tomsick T, Barsan W, Spilker J. Ultra-early evaluation of intracerebral hemorrhage. *J Neurosurg.* 1990;*72*:195-199. Crossref. PubMed.
5. Kwak R, Kadoya S, Suzuke T. Factors affecting the prognosis on thalamic hemorrhage. *Stroke.* 1983;*14*:493-500. Crossref. PubMed.
6. Franke CL, Versteege WM, van Gijn J. The best fit method: a simple way for measuring the volume of an intracerebral hemorrhage. *Neuroradiology.* 1988;*30*:73-75. Crossref. PubMed.
7. Steiner I, Gomori JM, Melamed E. The prognostic value of the CT scan in conservatively treated patients with intracerebral hematoma. *Stroke.* 1984;*15*:279-282. Crossref. PubMed.
8. Tuhrim S, Dambrosia JM, Price TR, Mohr JP, Wolf PA, Hier DB, Kase CS. Intracerebral hemorrhage: external validation and extension of a model for prediction of 30-day survival. *Ann Neurol.* 1991;*29*:658-663. Crossref. PubMed.