DOI: 10.1590/0004-282X20130084

ARTICLE

Hematoma volumes of spontaneous intracerebral hemorrhage: the ellipse (ABC/2) method yielded volumes smaller than those measured using the planimetric method

Volumes de hematomas em hemorragias intracerebrais espontâneas: o método da elipse (ABC/2) produziu volumes inferiores do que aqueles determinados pelo método planimétrico

Adriano Keijiro Maeda[1], Luiz Roberto Aguiar[2], Carolina Martins[3], Gerson Linck Bichinho[4], Munir Antônio Gariba[4]

ABSTRACT

Objective: To compare two different methods for measuring intracerebral hemorrhage (ICH) volume: the ellipse volume (called ABC/2), and the software-aided planimetric. **Methods:** Four observers evaluated 20 brain computed tomography (CT) scans with spontaneous ICH. Each professional measured the volume using the ABC/2 and the planimetric methods. The average volumes were obtained, and the intra- and inter-rater variability was determined. **Results:** There is an absolute 2.24 cm^3 average difference between both methodologies. Volumes yielded by the ABC/2 method were as much as 14.9% smaller than by the planimetric one. An intra-observer variability rate of 0.46% was found for the planimetric method and 0.18% for the ABC/2. The inter-observer rates were 1.69 and 1.11% respectively. **Conclusions:** Both methods are reproducible. The ABC/2 yielded hemorrhage volumes as much as 14.9% smaller than those measured using the planimetric methodology.

Key words: cerebral hemorrhage, tomography, evaluation studies.

RESUMO

Objetivo: Comparar dois métodos diferentes para determinar o volume da hemorragia intracerebral: volume da elipse (chamado ABC/2), e método planimétrico auxiliado por computador. **Métodos:** Quatro diferentes observadores avaliaram as imagens de 20 tomografias cerebrais com diagnóstico de hemorragia intracerebral espontânea. Cada profissional determinou o volume da hemorragia usando os dois métodos. Foram comparadas as médias dos volumes obtidos, bem como suas variabilidades intra e interobservadores. **Resultados:** Foi observada diferença estatisticamente significativa entre os volumes calculados por meio dos dois métodos, com uma variação média absoluta de 2,24 cm^3 e com volumes até 14,9% menores para o método ABC/2. A média da variabilidade intraobservador foi de 0,46% para o método planimétrico e 0,18% para o ABC/2. As taxas de variabilidade interobservador foram de 1,69 e de 1,11%, respectivamente. **Conclusões:** Ambos os métodos são reprodutíveis. O volume determinado pelo ABC/2 pode ser até 14,9% menor que aquele determinado pelo método planimétrico.

Palavras-Chave: hemorragia cerebral, tomografia, estudos de avaliação.

Cerebrovascular accidents (CVA) include ischemic cerebral attacks, subarachnoid hemorrhage, and spontaneous intracerebral hemorrhage (ICH). The latter is the deadliest type of CVA, accounting for 10% of total strokes[1,2]. Stroke is considered the third single cause of mortality in the United States of America, following cardiovascular diseases and neoplasms. In 2005, stroke was the cause of one in every 15 deaths in the USA, and 8 to 15% of patients with acute ischemic strokes and 37 to 38% of the cerebral hemorrhage ones died within 30 days[3]. In addition, only 20% of patients with ICH recovered functional independence, suggesting a poor prognosis for recovery[4].

Intracranial hypertension is considered the main reason for surgical indication in subjects with ICH, especially in cases in which there is a progressive neurological deterioration[5,6]. The

[1]MD, Postgraduate Health Technology Program, Pontifical Catholic University of Paraná, Curitiba PR, Brazil;

[2]MD, MsC, PhD, Postgraduate Health Technology Program, Pontifical Catholic University of Paraná; Neurosurgeon at Hospital Santa Cruz, Curitiba PR, Brazil;

[3]MD, PhD, Neurosurgeon at Hospital Pelópidas Silveira, Instituto de Medicina Integral Professor Fernando Figueira (IMIP), Recife PE, Brazil;

[4]MSc, PhD, Postgraduate Health Technology Program, Pontifical Catholic University of Paraná, Curitiba PR, Brazil.

Correspondence: Luiz Roberto Aguiar; Rua Imaculada Conceição 1.155; 80215-901 Curitiba PR - Brasil; E-mail: luiz.aguiar@pucpr.br

Conflict of interest: There is no conflict of interest to declare.

Received 26 March 2012; Received in final form 26 March 2013; Accepted 02 April 2013.

hemorrhage size, ventricular extension and expansion of the hematoma, along with altered level of consciousness, are decisive factors in the evolution of patients[7,8]. An increase in the ICH volume is a major contributor to poor prognosis, especially when it occurs early on, since it indicates neurological deterioration[9-14].

Given the importance of measuring accurately the hemorrhage lesion volume in properly determining patient prognosis, the aim of this study was to compare two methods that are currently used for determining spontaneous hemorrhage volume: the ellipsoid (or ABC/2), and the planimetric.

METHODS

This was a retrospective study, carried out from October 2007 to January 2008, approved by the Ethics and Research Committee of the Pontifical Catholic University of Paraná, in Curitiba, Paraná, Brazil.

The hematoma volumes of spontaneous ICH, using patients in the acute phase, were measured by two different methods (ABC/2 and the planimetric method) of computed tomography (CT) scans, obtained by volumetric acquisition in a Somaton® equipment (Siemens, Erlangen, Germany). The field of view (FOV) was selected at the time of examination according to patient's characteristics (weight and position) with a pitch of 1:1 and 3 mm thick cuts. Further reconstructions to 1 mm were made to all cuts.

Four independent raters evaluated the CT scans of 20 patients with spontaneous ICH, including five cases of posterior fossa and 15 of supratentorial hemorrhage. Bleeding was observed in 83 CT slices. Two measurements were made for each method (ABC/2 and planimetric) in two independent sessions, with at least a two-day interval. Volume measurements using the ABC/2 method were performed using DicomViewer® software (DicomWorks, Limoges, France). The images were transferred as DICOM files, and the tomography slices showing the hemorrhage were individually assessed. The slice with the largest area of hematoma was chosen for the measurements. Measure A corresponds to the greatest diameter of hemorrhage; B to the largest perpendicular diameter to A; whereas C was the sum of the thickness of slices containing the hemorrhage (Fig 1A). For the sum of the slice thickness (C), one was excluded if the hematoma area was smaller than 25% of the larger obtained place. Half of the slice thickness was taking into consideration if the measured area were between 25 to 75% when compared to the largest one, as proposed by Kothari et al.[15]. Values for A, B, and C were then multiplied, and the final result was divided by two, which was expressed in cm^3. Each observer performed two independent measurements using the ABC/2 method, with at least a two-day interval.

The planimetric measurements were performed using the planning station of BrainLab® neuronavigation equipment. The DICOM files of the CT images were transferred to the workstation using PatXFer® 2.0 and exported to Iplan® 2.6 Cranial software (BrainLab, Munich, Germany), a component of the utilities' package used for planning navigation. Hemorrhage edges were individually determined for each slice using the available software tools (brush and smartbrush), as seen in Fig 1B. This software calculates the total hemorrhage volume, expressed in cm^3.

The volumes obtained using the two methods were compared using Student's *t*-test for dependent samples, and the correlation between them was estimated using Pearson's correlation coefficient and tested for its major significance.

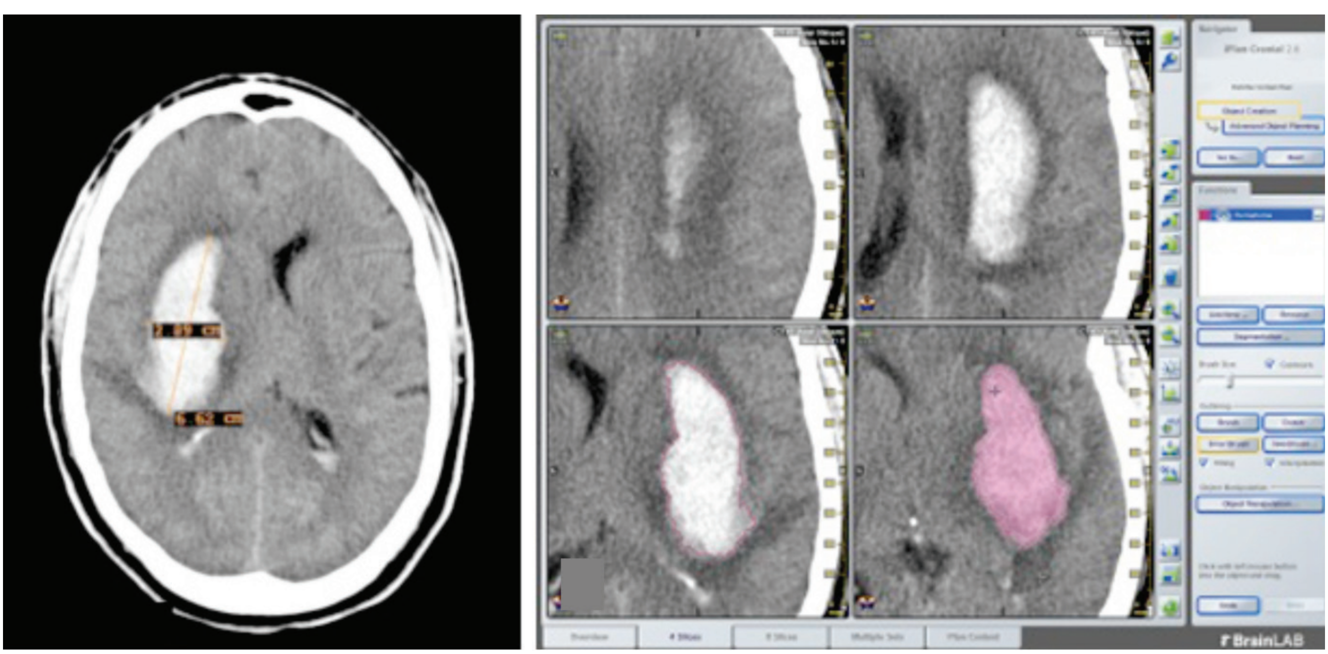


Fig 1. (A) Axial computed tomography scan slice displaying the method of linear measurement using DicomWorks software; (B) definition of the hematoma borders using Iplan (BrainLab, München).

The method error was determined, and the results were compared for inter- and intraobserver measurements using the variance model. The intraobserver error was determined by averaging the values obtained from each observer using both measurement methods (ABC/2 and planimetric method). The interobserver error was calculated applying the differences between the average values for every two observers, for the ABC/2 and planimetric methods.

RESULTS

There was a significant difference in the average volumes obtained using both methods, the absolute difference being 2.24 cm^3. The average measurement obtained with ABC/2 method was 14.9% lower than that obtained with the planimetric one. Table 1 and Fig 2 show average, minimum, and maximum values, which ranged from 25 to 75% of data. However, a good correlation between both methodologies can be observed as showed by Pearson's correlation coefficient, in the two methods (r=0.984; p<0.001), as seen in Fig 3.

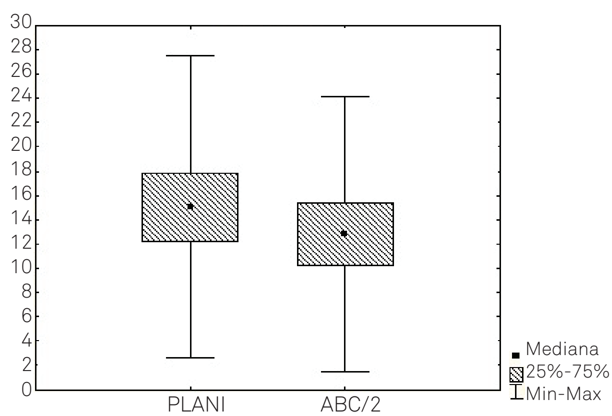
The intraobserver error is listed in Table 2 for ABC/2 method and in Table 3 for the planimetric.

The interobserver error was calculated using the differences between the average values for every two observers. Table 4 shows the results for ABC/2 and Table 5 for the planimetric method.

Table 1. Planimetric and ABC/2 method comparison.

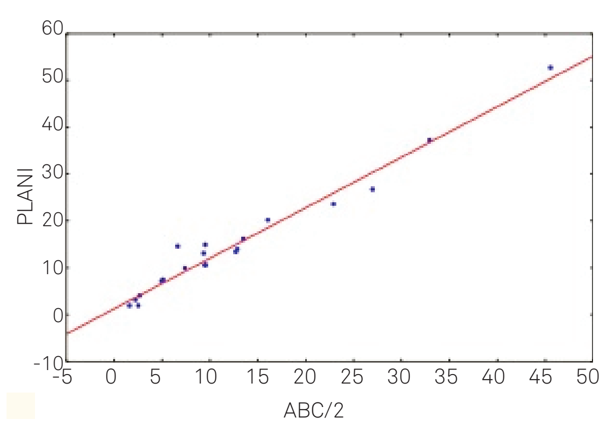
Method	Average (cm^3)	Standard deviation (cm^3)	p-value*
PLANI	15.04	12.46	
ABC/2	12.8	11.37	
(PLANI – ABC/2)	2.24	2.38	<0,001

*Student's *t*-test for paired samples; p<0.05.



ABC/2: ellipsoid; PLANI: planimetric.

Fig 2. Average and standard deviation for planimetric and ellipsoid method.



ABC/2: ellipsoid; PLANI: planimetric.

Fig 3. Pearson's correlation coefficient between planimetric and ellipsoid method (r=0.984; p<0.001).

DISCUSSION

The ABC/2 method provides an estimated value of the spontaneous ICH volume. Although several studies validate this method for clinical purposes[16-21], it is considered to be the most effective for measuring ICH that have a rounded or elliptical shape[20], as opposed to irregularly-shaped hemorrhages, which are in fact more common among patients who take anticoagulants[19].

In a previous study, Gebel et al.[20] used both methods (ABC/2 and planimetric) to compare volumes of

Table 2. Average values of ABC/2 from each observer and differences between them.

	Observer 1		Observer 2		Observer 3		Observer 4	
	Measurement		Measurement		Measurement		Measurement	
	1	2	1	2	1	2	1	2
Average (cm^3)	12.43	12.48	12.71	12.65	13.20	13.10	12.82	12.99
Difference (cm^3)	0.05		0.06		0.10		0.17	

Table 3. Average values of the planigraphic method from each observer and differences between them.

	Observer 1		Observer 2		Observer 3		Observer 4	
	Measurement		Measurement		Measurement		Measurement	
	1	2	1	2	1	2	1	2
Average (cm^3)	15.42	15.08	15.78	15.76	16.39	16.47	14.28	14.86
Difference (cm^3)	0.34		0.02		0.08		0.57	

intracerebral and subdural hematomas, and they found a good correlation between the two methods. However, these authors used different CT scan acquisition parameters. In another study, Kothari et al.[15] reported that, compared to the planimetric method, ABC/2 overestimates volumes by 1.5 (±1.3) cm^3. This tendency was also observed by Gebel et al.[20]. According to these authors, this overestimation appears to be correlated with lesion location, being more pronounced in brainstem, cerebellar, and lobar hemorrhages. The observed inaccuracy, in terms of variability between observers, obeys the same sequence. These studies also suggest an overestimation from 5 to 10% even for regular-shaped hemorrhages.

Yet, another study by Huttner et al.[19], compared the two measurement techniques, for ICH secondary to the use of oral anticoagulants, which, relative to spontaneous hemorrhages, are more often irregular in shape, as mentioned. They did not observe a statistically significant difference between the two methods; however, they found an overestimation by the ABC/2 method of 6.68% (±3.01) for regular (rounded or elliptical) hematomas, 14.85% (±4.95) for irregular ones, and 32.11% (±10.28) for multinodular or separate[19].

A recent study by Freeman et al.[16], by contrast, found that the ABC/2 technique underestimated the volume in four out of five ICH, and one case of subdural hematoma. For elliptic hemorrhages, there was a difference of 24% between the two methods, and another of 28% for other hematomas; the absolute average difference was of 6.7 and 38 cm^3, respectively[16].

Our findings are similar to those reported by Freeman et al.[16] – ABC/2 method resulted in an underestimation of volume when compared to the planimetric. It should be noted, however, that we did not classify our images as regular or irregular. Our study also suggests that the planimetric method is more precise, accurately measuring the hematoma area in a given slice and using the known slice thickness to determine volume.

When using ABC/2, Kothari et al. recommended excluding slice thickness if the area of hematoma in a given slice were smaller than 25% of the larger obtained, or taking into consideration only half of the slice thickness if the area were measured from 25 to 75% when compared to the largest one[15]. The fact that we adopted this rule for calculating the volume using the ABC/2 method may explain the underestimation of the hematoma volume in the current study.

Herein, we evaluated the systematic error in volume measurement by the ABC/2 and planimetric methods through comparing the average differences, which were determined for varied measurements obtained by the same researcher (intraobserver – Tables 2 and 4) and for those determined by different researchers (interobserver – Tables 3 and 5). For both methods, the percentage of intraobserver variability was lower than that of the interobserver one, with the planimetric method yielding higher variability than the ABC/2 method. Although the differences are not statistically significant, this is also an interesting finding, since the planimetric method, considered the golden-standard, showed more variability than the ABC/2. Fine automatic edge determination and more precise segmentation method could possibly alter this relationship.

Zimmerman et al[11]. compared the variability of ICH volume measurements using computer software with the determination of hematoma borders done by automatic and semiautomatic or manual segmentations. They showed minimal intra- and interobserver variations, supporting the validity of interpretations among different observers, which is similar to that found in our study[11].

The two volume evaluations performed in this study are dependent on the measurements carried out by the observers. The ABC/2 method requires determination of length, diameter, and thickness of the hematoma, while the planimetric requires demarcation of the borders of hemorrhage for volume calculation. The ABC/2 has already been validated and has the advantage of obtaining rapidly volumes. It can be performed at patient bedside, even without the use of computerized devices. The method of planimetry is more accurate in determining volume, though it needs the help of a suitable computer and software that is not always readily available. Therefore, a reliable method of automatic segmentation that can be used for more asymmetric lesions in order to improve not only the accuracy, but also velocity of results is not available.

Accurate hemorrhage volume measurements are essential for the appropriate management of patients. Development of mathematical algorithms for

Table 4. Difference of ellipsoid average values compared in every two observers (cm^3).

Differences	Measurement 1	Measurement 2
Between observers 1 and 2	0.28	0.17
Between observers 1 and 3	0.77	0.62
Between observers 1 and 4	0.39	0.51
Between observers 2 and 3	0.49	0.45
Between observers 2 and 4	0.11	0.35
Between observers 3 and 4	0.38	0.11

Table 5. Differences of average values in the planigraphic method compared in every two observers (cm^3).

Difference	Measurement 1	Measurement 2
Between observers 1 and 2	0.36	0.68
Between observers 1 and 3	0.97	1.39
Between observers 1 and 4	1.14	0.22
Between observers 2 and 3	0.62	0.72
Between observers 2 and 4	1.49	0.9
Between observers 3 and 4	2.11	1.62

automatically determining volume, with a faster and more accurate acquisition of data, can lead to better evaluation of these patients.

In conclusion, our results revealed that both methods are reproducible and intraobserver variability for both methods is lower than the interobserver one. We also observed that ABC/2 method yielded hemorrhage volumes as much as 14.9% smaller than those measured using planimetric method.

The results of this careful comparison between two methods carry important clinical implications for determining surgical treatment and thus represent a valuable contribution to the field.

References

1. Steiner T, Rosand J, Diringer M. Intracerebral hemorrhage associated with oral anticoagulant therapy: current practices and unresolved questions. Stroke 2006;37:256-262.
2. Manno EM, Atkinson JL, Fulgham JR, Wijdicks EF. Emerging medical and surgical management strategies in the evaluation and treatment of intracerebral hemorrhage. Mayo Clin Proc 2005;80:420-433.
3. Thom T, Haase N, Rosamond W, et al. Heart disease and stroke statistics - 2006 update: A report from the american heart association statistics committee and stroke statistics subcommittee. Circulation 2006;113:85-151.
4. Mayer SA, Brun NC, Begtrup K, et al. Recombinant activated factor VII for acute intracerebral hemorrhage. N Engl J Med 2005;352:777-785.
5. Gregson BA, Mendelow AD. International variations in surgical practice for spontaneous intracerebral hemorrhage. Stroke 2003;34:2593-2597.
6. Radberg JA, Olsson JE, Radberg CT. Prognostic parameters in spontaneous intracerebral hematomas with special reference to anticoagulant treatment. Stroke 1991;22:571-576.
7. Davis SM, Broderick J, Hennerici M, et al. Hematoma growth is a determinant of mortality and poor outcome after intracerebral hemorrhage. Neurology 2006;66:1175-1181.
8. 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.
9. Kazui S, Minematsu K, Yamamoto H, Sawada T, Yamaguchi T. Predisposing factors to enlargement of spontaneous intracerebral hematoma. Stroke 1997;28:2370-2375.
10. Leira R, Davalos A, Silva Y, et al. Early neurologic deterioration in intracerebral hemorrhage: predictors and associated factors. Neurology 2004;63:461-467.
11. Zimmerman RD, Maldjian JA, Brun NC, Horvath B, Skolnick BE. Radiologic estimation of hematoma volume in intracerebral hemorrhage trial by CT scan. AJNR 2006;27:666-670.
12. 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.
13. Juvela S, Kase CS. Advances in intracerebral hemorrhage management. Stroke 2006;37:301-304.
14. Brott T, Broderick J, Kothari R, et al. Early hemorrhage growth in patients with intracerebral hemorrhage. Stroke 1997;28:1-5.
15. Kothari RU, Brott T, Broderick JP, et al. The ABCs of measuring intracerebral hemorrhage volumes. Stroke 1996;27:1304-1305.
16. Mahaley MS Jr., Gillespie GY, Hammett R. Computerized tomography brain scan tumor volume determinations. Sensitivity as an objective criterion of response to therapy. J Neurosurg 1990;72:872-878.
17. Freeman WD, Barrett KM, Bestic JM, Meschia JF, Broderick DF, Brott TG. Computer-assisted volumetric analysis compared with ABC/2 method for assessing warfarin-related intracranial hemorrhage volumes. Neurocrit Care 2008;9:307-312.
18. Sucu HK, Gokmen M, Gelal F. The value of XYZ/2 technique compared with computer-assisted volumetric analysis to estimate the volume of chronic subdural hematoma. Stroke 2005;36:998-1000.
19. Huttner HB, Steiner T, Hartmann M, et al. Comparison of ABC/2 estimation technique to computer-assisted planimetric analysis in warfarin-related intracerebral parenchymal hemorrhage. Stroke 2006;37:404-408.
20. Gebel JM, Sila CA, Sloan MA, et al. Comparison of the ABC/2 estimation technique to computer-assisted volumetric analysis of intraparenchymal and subdural hematomas complicating the GUSTO-1 trial. Stroke 1998;29:1799-1801.
21. Gomez-Marino R, Andre C, Novis SA. [Volumetric determination of cerebral infarction in the acute phase using skull computed tomography without contrast: comparative study of 3 methods]. Arq Neuropsiquiatr 2001;59:380-383.