Calculating the tumor volume of acoustic neuromas: Comparison of ABC/2 formula with planimetry method

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ABSTRACT

Objective: The ABC/2 equation is commonly applied to measure the volume of intracranial hematoma. However, the precision of ABC/2 equation in estimating the tumor volume of acoustic neuromas is less addressed. The study is to evaluate the accuracy of the ABC/2 formula by comparing with planimetry method for estimating the tumor volumes.

Methods: Thirty-two patients diagnosed with acoustic neuroma received contrast-enhanced magnetic resonance imaging of brain were recruited. The volume was calculated by the ABC/2 equation and planimetry method (defined as exact volume) at the same time. The 32 patients were divided into three groups by tumor volume to avoid volume-dependent overestimation (<3 ml, 3–6 ml and >6 ml).

Results: The tumor volume by ABC/2 method was highly correlated to that calculated by planimetry method using linear regression analysis ($R^2 = 0.985$). Pearson correlation coefficient ($r = 0.993$, $p < 0.001$) demonstrates nearly perfect association between two methods.

Conclusions: The ABC/2 formula is an easy method in estimating the tumor volume of acoustic neuromas that is not inferior to planimetry method.

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1. Introduction

Acoustic neuromas can destroy the quality of life through affecting hearing impairment [1]. Therapeutic options for acoustic neuroma have been well-developed including microneurosurgery, Gamma-knife, linear accelerator, proton beam and CyberKnife® stereotactic radiosurgery [2–5].

Bassim et al. conducted a critical review of 56 literature regarding radiation therapy for the treatment of acoustic neuromas [6]. They pointed out a crucial issue that the lack of uniform, objective reporting standards for estimating tumor size. Moreover, the definition of tumor control among those 56 articles is not well-established. Undoubtedly, it is a fundamental issue to create a standard, scientific, objective, and accurate calculation method to precisely quantify the tumor volume of acoustic neuromas [7,8] to provide for therapeutic decision making [9,10], outcome prediction, and preservation of hearing and facial function after treatment [11,12].

The ABC/2 method has been broadly used in calculating the volume of cerebral hematoma for many years due to its rapidity and easy accessibility [13,14]. However, the accuracy of the ABC/2 formula in evaluating the tumor volume of acoustic neuromas is not yet clearly identified. In this study, we used the ABC/2 formula comparing with standard planimetry method to calculate the tumor volume of acoustic neuromas. The statistical analyses of the above two methods for tumor volume calculation in acoustic neuromas were discussed.

2. Methods

2.1. Patient population

This study was approved by the Institutional Review Board of Tri-Service General Hospital, National Defense Medical Center, Taipei, Taiwan (TSGHIRB approval Number: 1–101–05–003). Between January 2007 and December 2011, 32 patients with acoustic neuroma recruited in this study, age ranging from 20 to 84 years old (mean age 51 years) and the ratio of male to female was 1:1.

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Abbreviations: IAC, internal auditory canal; MRI, magnetic resonance imaging.

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Table 1
A total of 32 cases recruited in tumor volume study of acoustic neuromas.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>n</th>
<th>(%)</th>
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<td>Gender, men</td>
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<td>50.0</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
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<tr>
<td>&lt;30</td>
<td>2</td>
<td>6.3</td>
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<tr>
<td>30–50</td>
<td>11</td>
<td>34.4</td>
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<tr>
<td>&gt;50</td>
<td>19</td>
<td>59.4</td>
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<tr>
<td>Exact volume* (ml)</td>
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<td></td>
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<tr>
<td>&lt;3</td>
<td>10</td>
<td>31.3</td>
</tr>
<tr>
<td>3–6</td>
<td>6</td>
<td>18.8</td>
</tr>
<tr>
<td>&gt;6</td>
<td>16</td>
<td>50.0</td>
</tr>
</tbody>
</table>

* Exact volume was defined by planimetry.

2.2. Imaging acquisition and data analysis

Contrast-enhanced brain MRI (T1-weighted, axial view) [15] were used in our study. The tumor volume was calculated by the planimetry method (by DY Hueng) and estimated with the ABC/2 method (by YL Yu) respectively by the two observers to keep the inter-observer agreement. Both observers were blinded to the data of each other. In the ABC/2 formula, the maximal length (A), width (B), and height (C) of the tumor were acquired on the browser of our picture archiving and communication system (PACS, EBM Technology). Parameter A represents the maximal diameter of the tumor measured on the axial image, parameter B represents the 90 degrees to A, and parameter C represents the product of the slice thickness and the number of slices of images [13]. In the planimetry method, the tumor was labeled from each slice and the data acquired were copied to a personal computer for analysis. The tumor volume was calculated by multiplying the sum of labeled area by the slice thickness.

2.3. Grouping by tumor volume

The 32 patients were divided into three groups by tumor volume calculated by planimetry method. Group 1 contained 10 patients with tumor volume less than 3 ml; group 2 contained 6 patients with tumor volume between 3 ml and 6 ml; and group 3 contained 16 patients with tumor volume greater than 6 ml.

2.4. Statistical analysis

Paired-t test was used to compare difference between tumor volumes acquired using the ABC/2 and planimetry method. Pearson correlation and linear regression analyses were used to appraise the relationship between two methods. We further carried out the Bland–Altman plots to illustrate the agreement between two methods by using MedCalc® statistical software (Version 12.2.1.0). P value <0.05 is defined as statistically significant.

3. Results

A total of 32 patients with equal numbers of men and women were recruited in this study. Almost 60% patients (n = 19) were older than 50 years, and only 6% (n = 2) were younger than 30 years. To avoid volume-dependent misestimation, the 32 patients was divided into 3 groups by tumor volume (<3 ml, 3–6 ml and >6 ml) estimated by the planimetry method. Accordingly, there were 10, 6 and 16 patients in each group (Table 1).

The average tumor volume was 8.04 ml and 8.38 ml when calculated by ABC/2 equation and planimetry method respectively and revealed no statistically significant difference. Pearson correlation coefficient (r = 0.993, p < 0.001) demonstrates nearly perfect correlation between two methods. The tumor volume calculated by ABC/2 method was found to be highly correlated to that calculated by planimetry method using linear regression analysis (Fig. 1, $R^2 = 0.985$). The equation of exact volume is equal to 0.099 + 1.061 $\times$ ABC/2. The agreement between ABC/2 method and planimetry method is presented by the Bland–Altman plots (Fig. 2A). After grouping, the measured volume differences between two methods still fall into acceptable range (±1.96 SD) regard-
less of tumor volume (Fig. 2B). The representative T1-weighted contrast-enhancing magnetic resonance images from each group were shown in Fig. 3.

4. Discussion

Calculating the volume of acoustic neuroma precisely is a clinically crucial issue. The volume of acoustic neuroma is broadly utilized to predicting disease outcome, evaluating treatment response and making treatment plan. Hence, we calculated the tumor volume of acoustic neuromas. Our study demonstrated that the volume of acoustic neuroma estimated by the ABC/2 formula was highly correlated to that measured by planimetry method ($r = 0.993, p < 0.001$). Moreover, thirty-two patients were divided into three groups by tumor volume estimated by planimetry method [16] (i.e. exact volume) to measure the tumor volume difference. We found that there was no statistical difference between the two methods in estimating the volume of acoustic neuroma. These results indicate that the ABC/2 formula is an easy and quick access in estimating the tumor volume of acoustic neuromas that is not inferior to planimetry method.

The ABC/2 formula is conventionally applied in calculating hematoma under the assumption that the shape of hematoma is ellipsoid or ovoid [17,18]. However, previous hematoma volume study showed that the ABC/2 method harbored a problem of volume-dependent overestimation of hematoma volume [19]. The underlying mechanism is due to the nature of hematoma lesion may form separated hematomas. Moreover, warfarin-induced irregular shape of hematomas leads to the overestimation of hematoma volume by the ABC/2 formula [18]. Unlike the rapid formation of hematoma lesion, the acoustic neuromas grow slowly and present with ovoid shape [20]. In cases that tumor presented with an enhancing tail, Salzman et al. [21] (a portion of IAC invasion), the tumor shape can be further classified into dumbbell, lollipop or cone-shaped [22]. Any of which can make the tumor shape more irregular than pure ovoid and cause confusion in the determination of parameter $A$ or $B$ in the ABC/2 method. In our study, the whole tumor was encircled as much as possible to include the portion within IAC. When the “tail” is close to the main tumor part, the whole “tail” may be counted in the measurement of $A$ or $B$ (Fig. 4A). In contrast, if the tail is away from the tumor, part of the “tail” near the base may still be encircled with a little portion excluded from the ovoid shape we drew (Fig. 4B). Under

Fig. 4. (A) Representative image for the portion within IAC is counted in the measurement of b. l: The portion within IAC (B) Representative image for the portion within IAC is partly excluded. I: The portion within IAC.
maximum inclusion and least exclusion of the portion within IAC, the measured volume differences between two methods still fall into acceptable range (±1.96 SD) regardless of tumor volume. In comparison with hematoma volume study, the volume-dependent effect is not apparent in tumor volume study of acoustic neuromas. Therefore, the application of ABC/2 formula in acoustic neuroma is still reliable, even in acoustic neuromas with greater volume when the shape is nearly ovoid.

5. Conclusions

For most patients with typical ovoid-shaped acoustic neuroma, the ABC/2 formula may serve as an easy and quick access in estimating the tumor volume of acoustic neuromas that is not inferior to planimetry method. Since Lupponi et al. reported a better volume prediction of planimetric method with lower slice thickness in MRI study [23]. The ABC/2 method may be useful in the serial follow-up of tumor volume after treatment especially with MRI studies with larger slice thickness. When the slice thiness increased in the MRI study, the accuracy of planimetric method for volume comparison may be lowered owing to systemic bias. For the ABC/2 method, it takes only one representative image to determine the parameter A and B and may make the comparison more easy and better reflect the true tumor volume under the assumption of an ovoid-shaped tumor. However, this point of view may need more future research to clarify due to limited case numbers. Though not encountered in our cases, the use of the ABC/2 method may be limited in rare cases with extremely irregular-shaped tumor to avoid volume-dependent overestimation [17]. In this condition, the planimetric method under MRI with least slice thickness may remain the first choice.

Conflicts of interest

The authors declare no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Contributors

YL Yu, data acquisition, and drafting manuscript; CJ Juan, study supervision, critical revision of the manuscript, and critical revision of the article; MS Lee, statistical analysis and critical revision of the article, and study supervision; DY Hueng, conception and design, data acquisition, critical revision of the article, and study supervision.

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References
