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NEW OPTION FOR RELIABLE FAST INDIRECT VOLUMETRY: THE XYZ GEO METHOD

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Abstract: Objectives: present a simple, fast and reliable method to determine the volume of brain pathologies by applying the formula of the geometric figure that best fits the lesion studied. **Material and method:** retrospective study on 403 tumor lesions of different histology found in 172 patients treated by radiosurgery at the Dominican Gamma Knife Center (CGKD), using 1.5 and 3.0 Tesla MRI images with thin cuts for three-dimensional reconstruction. The volume of each of them was determined following the voxel method (planimetry) in which the edges of the lesion are painted in each slice. We immediately proceeded to determine if the lesion was Ellipsoidal, Cubic, Cuboid or other. More than 98% of the lesions were ellipsoid-shaped, about 1% were cubic. Applying the formula of the figure in question in each case and starting from the center of the structure, the XYZ diameters used internationally to define the stereotactic dimensions of the space were drawn. Thus, the Theoretical Volume was determined, which was compared to the Real Volume of each lesion using the Student's T Test to establish the Mean between two measurements, then they were correlated using the Wilcoxon Test and the Spearman's Rang Test. **Results:** If the lesion was ellipsoidal and we used the correct formula, the result was close to 93% of the Real Volume. If the Ellipsoid formula was applied to a cubic lesion, we obtained 178% of the Real Volume. If a Cubic lesion was measured with the corresponding formula, the result only exceeded the Real Volume by 12%. Conclusion: the XYZ Geo Method offers an option for rapid indirect volumetry very close to the real volume of the intracranial lesion if the geometric formula that best defines the lesion studied is applied, respecting the principles established for measuring its diameters on an imaging platform with option to calculate the three dimensions of stereotactic space (XYZ).

Keywords: Indirect Volumetry, Planimetry, Radiosurgery, Gamma Knife, Brain Tumors.

INTRODUCTION

As the Radiation Oncologist Fabio Valenzuela Sosa demonstrated conclusively in his treatise on the Sosa Model: knowing the exact Volume in cubic centimeters (cc) of the lesion is essential to be able to treat it adequately, the simple determination of the "largest diameter" of the lesion as a guide to determine the dose of radiosurgery to be used to treat it, it can lead to the use of an inadequate dose and a catastrophic therapeutic result[1].

Until a few years ago, the manuals for the treatment of brain injuries through Radiosurgery made reference to the largest diameters measured in millimeters of the lesions and not to their real volume in cubic centimeters (cc) when recommending appropriate doses[1].

This erroneous behavior, accepted for years by many centers of excellence around the world, led the neuro-oncology community to think for quite some time that Vestibular Schwannomas did not grow or grew very slowly. A Danish study published in Neurosurgery in 2017 reported that a 10-year follow-up of 156 Vestibular Schwanomas demonstrated growth "in only a minority of patients." In that study, only two-dimensional volumetry was done[2].

Multicenter studies had to arrive with exact real volumetry of Vestibular Scwannomas based on the determination of their contours in each high-definition 1.5 Tesla MRI slice, to establish that these tumors grew each year at a non-negligible percentage of 33.5% and that a third of them doubled their size every 12 months[3].

Hence, in our daily practice we defend the performance of a volumetric study that is as accurate as possible before treating any type of intracranial injury through Radiosurgery.

But determining the real volume using the voxel method, painting slice by slice on the screen of the stereotactic management platform of high-definition Magnetic Resonance images (planimetry), takes many minutes and automatic segmentation software based on artificial intelligence and "deep learning" are not available in most of our health centers[4,10]. For this reason, having a rapid indirect volumetry option has become a necessity in the daily work of those who treat brain injuries using Radiosurgery, manage intraparenchymal hematomas of hypertensive patients or extensive hemorrhagic contusions, for example. To make therapeutic decisions regarding radiation doses to treat a brain tumor; use or not of mannitol, evacuation or conservative management in the event of intrahemispheric bleeding, etc., knowing the volume of the lesion is a peremptory necessity. Since 1996, the ABC/2 Method has been used in the world for this purpose, especially when intraparenchymal hemorrhages are managed[5], but dissonant voices have appeared pointing out the inaccuracy of this resource if applied to arteriovenous malformations[6]. It is fair to recognize that there is still a long way to go in obtaining an ideal method for indirect volumetry of intracranial lesions.

MATERIAL AND METHODS

This retrospective study was carried out at the Dominican Gamma Knife Center based on 403 intracranial tumors detected in 172 patients treated between 2011 and 2015. These included 119 women and 53 men, average age of 57 years. Metastases constituted 61.5%, Meningiomas 20.6%, Pituitary Adenomas 9.2% and Acoustic Neuromas 5.2% (Table 1). All benefited from a contrasted MRI of thin sections to facilitate three-dimensional reconstruction on the Elekta Work Station Gamma Plan 10 image processing platform in which Radiosurgery treatments are planned using Gamma Knife. Real volumetry based on voxels (planimetry) was performed on each of the lesions, in which the contours that appear in each MRI slice are painted (usually T1 sequence with contrast). Although this is the only way to obtain the exact volume of a lesion, this process takes many minutes. In order to have a more expeditious alternative to obtain an indirect volume close to the real one, we thought of applying the formula of the geometric figure that best fits the appearance of the lesion studied. 98.26% of the lesions fit the figure of the Ellipsoid whose simplified geometric formula we calculated must be XYZ/1910 (Figure 1, Table 2). To name the diameters we use the international language of Stereotaxy in which: (mm) always taken a trajectory perpendicular to the opposite side of the structure. 0.99% resembled a Cube (formula: XYZ/1000). Very few lesions fit a Cuboid or an Ellipsoidal Cuboid; in those cases, when applying the cube formula, the approximation to the real volume was very narrow (Table 2). Indirect volumetry determined by this method, which we agree to call XYZ GEOMETRIC (XYZ GEO) for obvious reasons, only takes a few seconds. All data collected was processed in SPSS software, IBM, 15.0, Chicago, IL. The Student's T Test was used to establish the average difference between two measurements, which were correlated using the Wilcoxon Test and the Spearman's Rang Test, the results of which were displayed in a scatter graph (Figure 2).

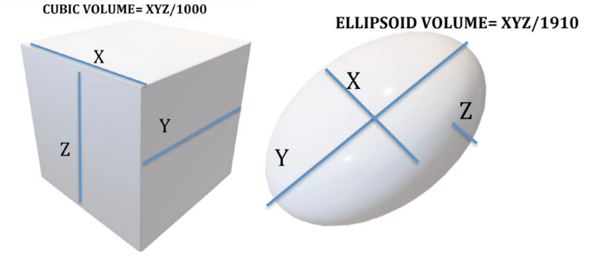


FIGURE 1

APPLYING THESE 2 FORMULAS, DEPENDING ON THE SHAPE

403 LESIONS TREATED IN THE DOMINICAN GAMMA KNIFE CENTER

HISTOLOGY	#	%
MENINGIOMA	83	20.6
MYELOMA	1	0.2
MEDULLOBLASTOMA	1	0.2
LOW GRADE GLIOMA	1	0.2
PITUITARY ADENOMA	37	9.2
ACOUSTIC NEUROMA	21	5.2
METASTASIS	247	61.5
MALIGNANT GLIOMA	4	1.0
CRANIOPHARYNGIOMA	4	1.0
GERMINOMA	1	0.2
CHORDOMA	1	0.2
GLOMUS JUGULARE	2	0.5
TOTAL	403	100.0

TABLE 1

OF THE TUMOR, WE WEREABLE TO OBTAIN A VOLUME VERYCLOSE TO THE REAL IN ALL LESIONS

SHAPE IN 403 LESIONS TREATED IN THE DOMINICAN GAMMA KNIFE CENTER

GEOMETRIC FORM OF THE LESION	NUMBER OF CASES	PERCENTAGE
ELLIPSOID	396	98.26%
CUBIC	4	0.99%
CUBOID	1	0.25%
CUBOID+ELLIPSOID	2	0.50%
TOTAL	403	100%

TABLE 2

RESULTS

Of the 403 intracerebral lesions studied, 98.26% that fit the shape of the Ellipsoid (Table 2) were volumetric using the voxel method (Real Volume = VR) and an average of 4.737568 cc was obtained. By applying the geometric formula of the Ellipsoid (XYZ/1910) an average of 4.4062 cc (Indirect Theoretical Volume) was achieved, for a 93% approximation to the Real Volume (Table 3). From here it can be deduced that using the geometric formula that corresponds to it, we can have an idea of the volume of any lesion in a few seconds that is quite close to 100%

of the Real Volume (VR), which can only be obtained after a process of long minutes painting section by section the contours of the structure studied on the screen of the Magnetic Resonance image processing platform that we are using (planimetry). This means an important gain of time for the specialist who is planning his therapeutic protocol, with a very adequate guarantee of accuracy. When we used the cube formula (XYZ/1000) in an ellipsoidal lesion, the average volume obtained was 178% of the real volume (Table 3). On the contrary, if we apply the cube formula in clearly cubic lesions (4 cases in our series), the VR was only exceeded by 12% (Table 4). In the few lesions whose shape was more compatible with a Cuboid or an Ellipsoidal Cuboid, the cube formula gave results closer to the VR (Table 4). As can be seen in Tables 5 and 6, the measures of central tendency and Spearman's Correlation were very close when comparing the VR of the lesions with the Theoretical Volume acquired by applying the XYZ Geo method using the ellipsoid formula when they assumed that way. The Scatter Graph shown in Figure 2 shows the close proximity of the results of both volumetry methods. Figures 3, 4 and 5 are very eloquent to demonstrate the practical application of the XYZ Geo Method of Indirect Volumetry in ellipsoidal and cubic brain lesions.

REAL VOLUME	CUBIC VOLUME	ELLIPSOID VOLUME	SHAPE OF THE LESION
18.6700	16.45	8.61	Cuboid +Ellipsoid
4.2800	4.47	2.34	Cuboid +Ellipsoid
1.4400	1.63	0.86	Cube
0.0600	0.06	0.03	Cube
2.3500	2.81	1.47	Cube
0.5700	0.65	0.34	Cube
2.0100	2.45	1.28	Cuboid

TABLE 4 NON ELLIPSOID VOLUMES(IN CC)

Central tendency measurements

		Voxel Method	XYZ / 1910	Difference
Mean volume		4.75 cm³	4.45 cm ³	0.30 cm³
Minimum		0 cm³	0 cm³	0
Maximum		57 cm³	50 cm³	7 cm³
Variance		59.8	54.0	5.8
Typical deviation		7.73	7.35	0.38

TABLE 5

Spearman's Correlation

		XYZ / 1910	Voxel Method
XYZ / 1910	spearman Correlation	1	.99(**)
	Sig. (bilateral)		.002
	N	396	396
Voxel Method	spearman correlation	.99(**)	1
	Sig. (bilateral)	.002	
	N	396	396

There is a significant correlation at 0, 02 level (bilateral)

TABLE 6

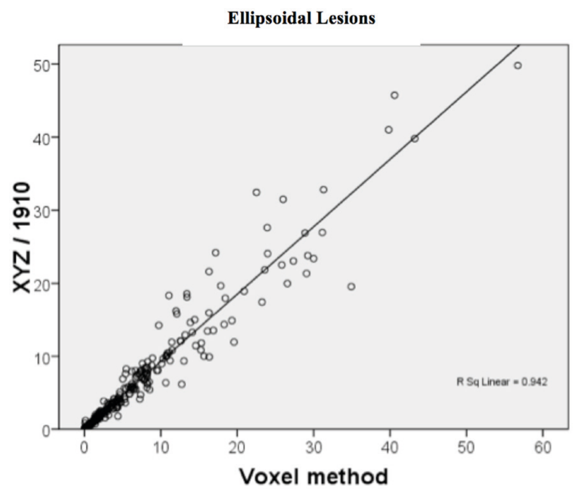


FIGURE 2

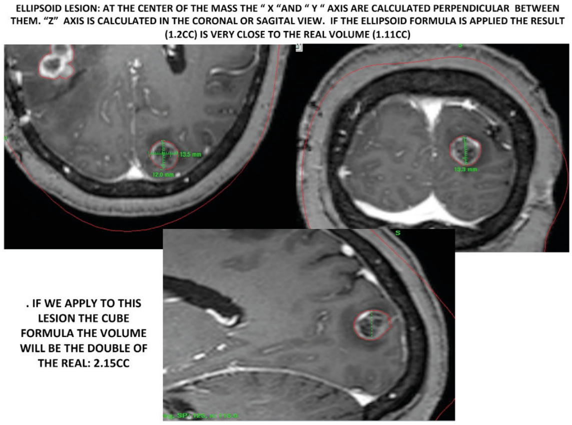


FIGURE 3

FORMULA TO OBTAIN VOLUME		CUBIC VOLUME	ELLIPSOID VOLUME	REAL VOLUME (VOXELS)
LESIONS	VALIDS	403	403	403
	LOST	0	0	0
MEDIA		8.4140	4.4062	4.737568
MEDIAN		2.1500	1.1281	1.380000
FASHION		.09	.05	.0100
TIP.DEVIATION		13.95302	7.30385	7.7093603
VARIANCE		194.687	53.346	59.434
MINIMUM		.01	.00	.0010
MAXIMUM		95.10	49.80	56.7200

TABLE 3: VOLUMETRIC RESULTS IN CC APPLYING ELLIPSOID(XYZ/1910) AND CUBIC(XYZ/1000)FORMULAS

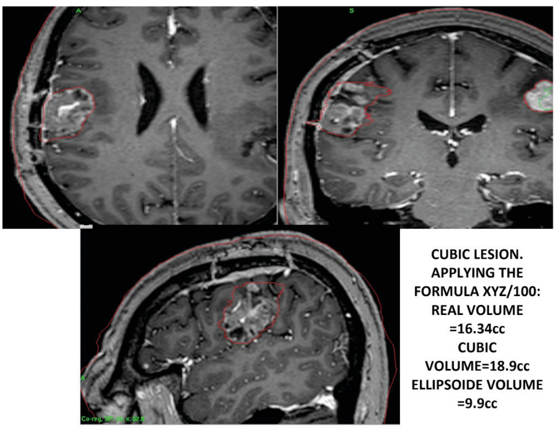
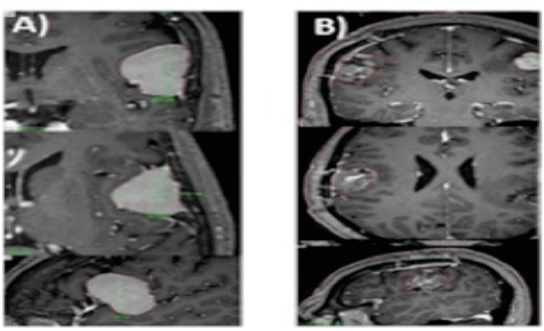


FIGURE 4



A) Ellipsoidal Convexity meningioma. Real volume: 11.67 cc. XYZ GEO Method: 12cc

B)Cuboidal brain metastasis. Real Volume: 16.34cc. XYZ GEOMethod: 18.9cc

FIGURE 5

DISCUSSION

Until this moment, the ABC/2 formula had been the most used to determine the volume of intracranial lesions.[5,7,8,9], particularly intraparenchymal hematomas. Recently, dissatisfaction has been felt due to the erroneous results of indirect volumetry of Arteriovenous Malformations using this method[6]. The reasons underlying these discordant results could be many, but we are convinced that one of the main reasons lies in attempting to indirectly measure any lesion using the modified ellipsoid formula without taking into account its particular geometric shape. Gathering all the geometric knowledge accumulated since ancient Greece, after careful observation, following the guidelines of the proposed method (XYZ GEO), the geometric figure that best fits the lesion studied is determined, its center is located, and the the three axes of space: The largest diameter is always chosen, drawn perpendicular to the opposite axis. After careful study, the original formula of the Ellipsoid (4/3π(A/2)(B/2)(C/2)) was brought to an exact simplification, obtaining XYZ/1910 as an ideal model. The same exercise was carried out with the XYZ/1000 Cube formula, always measuring the diameters in millimeters to obtain the volume in cubic centimeters (cc). When analyzing 403 brain tumors, the vast majority fit the shape of the Ellipsoid (Table 2) and when its formula is applied it approaches 93% of the real volume determined by voxels (Table 3). If the ellipsoid formula is applied in front of a cuboidal lesion, the results were very far from the real volume. But if the cube formula is used in the lesion that took that shape, the real volume and the theoretical volume determined by applying the cube formula were significantly closer (Table 4). In 1996, the date of publication of the ABC/2 method, Helical Tomographs with the capacity to reconstruct coronal and sagittal sections acquired axially were scarce, which is why its promoters recommend several complicated maneuvers to obtain the C or vertical axis (Z). Currently, rapid reconstruction in the sagittal and coronal axes is achieved in the workstation of the simplest helical tomographs (16 slices), obtaining without any difficulty the 3 axes of space to determine the rapid indirect volumetry using the corresponding geometric formula. In addition, there is free software available on the CD where the patient is given their Tomography or Magnetic Resonance images (RadiAnt DICOM Viewer™) that allows the different axes of space to be traced, being able to complete any geometric formula that is necessary using a simple LapTop and a CD player. The indirect volumetry process is no longer done at the patient's bedside as the authors of the ABC/2[5] method preach, but rather at the tomographer's workstation or on the treating doctor's LapTop. As can be seen, the advances in imaging technology experienced in the last 3 decades have refined the possibilities of visualization/delimitation of intracranial lesions and improved the capabilities for their direct and indirect volumetry.

CONCLUSION

Direct real volumetry consumes many minutes for a therapist who is usually too busy and impatient. Given the shortage in most of our health centers of software for automatic segmentation based on artificial intelligence and deep learning, using reliable indirect volumetry methods that are performed in seconds, whose results are adequately close to the real volume, can solve this problem. dilemma that arises in everyday medical practice when dealing with brain injuries such as tumors, intraparenchymal hemorrhages, hemorrhagic contusions, hippocampal atrophy, etc. In this research, the usefulness of the indirect volumetry method named XYZ GEO is clearly revealed since it applies the simplified geometric formula of any lesion to obtain its theoretical rapid volume based on the determination of its fundamental diameters in any treatment of tomography or magnetic resonance images following the simple, easily reproducible rules outlined. The significant number of injuries studied (more than 400) and the systematic application of reliable statistical instruments give robustness and reliability to the results. In future research we intend to enrich the validation of this proposal by applying the formula to ellipsoidal structures such as the Hippocampus and the Trigeminal Nerve, whose volumetry is essential to manage pathologies as prevalent as Temporal Lobe Epilepsy, Alzheimer's Disease or Trigeminal Neuralgia.

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