

A COMPARATIVE STUDY OF ORTHOGONAL PLANES FOR DIFERENTIAL DIAGNOSIS OF BRAIN TUMOR LESIONS THROUGH MRI

Smitha Haridas^{1,*}, Meena Devi Vimala kumari Nagendra Prasad², Vinoo Jacob³ and Sreekanth Kavitha Sivaraman⁴

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Abstract

Magnetic Resonance Imaging (MRI) is a sensitive tool, for differential diagnosis of normal as well as abnormal structures of internal organs. MRI provides superior structural characterization by capturing the cellular, vascular, metabolic and functional properties for differential diagnosis of brain tumors by measuring volume, axial, sagittal and coronal planes through two dimensional slices. The aim of the study is to characterize and identify the orthogonal imaging planes to detect brain tumor lesions through MRI. This study included 69 patients, both males and females, suspected of brain lesions and underwent MRI for diagnosis. The variations in the volume of the anatomical structures were measured and compared the planes as axial/sagittal, axial/coronal and coronal/sagittal for tumor brain lesions. The present study revealed that there is difference in the measurement of volume in tumor lesions in orthogonal planes (axial, sagittal and coronal). It was found that the volume of axial planes is measured as larger volume than the sagittal and coronal planes in tumor lesions. Statistical Analysis was done by SPSS version 16 software. The quantitative variables were expressed in mean and standard deviation (SD). Two way/Friedman Test were used for comparing the three groups. Statistically there was a significant difference between coronal and axial planes. From this study it is concluded that, in most of the brain lesions irrespective of the type of tumors, axial planes helps more in the detection of tumor volume as compared to sagittal and coronal planes for precise diagnosis of brain lesions.

Keywords: Brain tumor, Magnetic Resonance Imaging, Axial, Sagittal, Coronal, Tumor Volume

Introduction

A Magnetic resonance imaging (MRI) has been well established for both diagnosis and research to provide excellent soft-tissue delineation of different areas of interest (Jacobs *et al.*, 2007). MRI is also act as a sensitive tool for the diagnosis of normal as well as abnormal structures of brain (Zivadinov *et al.*, 2008). In modern neuroimaging, MRI permits

superior structural characterization by capturing the cellular, vascular, metabolic and functional properties of brain tumors (Javier *et al.*, 2017). It is a non invasive method that uses non ionising radiation and provides 3-dimensional reconstruction of organs from multiple contiguous images (Gates *et al.*, 1994). Modern technical developments,

¹ Department of Physics, Noorul Islam Centre of Higher Education, Kumarakovil, Kanyakumari, Tamil Nadu & Department of Physiology, Sree Gokulam Medical College & Research Foundation, Venjaramoodu.P.O, Trivandrum-695607

² Departments of Physics, Noorul Islam Centre of Higher Education, Kumarakovil, Kanyakumari, Tamil Nadu.

³ Department of Radio Diagnosis, Sree Gokulam Medical College & Research Foundation, Venjaramoodu.P.O, Trivandrum-695607

⁴ Department of Biochemistry, Sree Gokulam Medical College & Research Foundation, Venjaramoodu.P.O, Trivandrum-695607

* Corresponding author

including surface coils, fat suppression techniques, fast gradient-echo pulse sequences, and MR contrast agents provide excellent spatial and contrast resolution of the soft tissues with direct multi planar imaging. It allows diagnosing the lesion itself and the effect it has on the surrounding structures (Nayak *et al.*, 2013). MRI produces an image of thin slice through the human body. (Onwu *et al.*, 2014) As already established, for detecting tissue pathology for tumors, multiple MRI contrasts via sequential acquisition of images with different weighting including T1 weighted (T1w), T2 weighted (T2w) and proton density (PD) images can be used. (Misaki *et al.*, 2015) It is evident that evaluation of signal intensity for the T1wt and T2 wt images have a significant role in tumor detection (Smitha *et al.*, 2020). The magnetic resonance image (MRI) and its inherent contrast are controlled by a various anatomical structures and sequence-dependent parameters (McMahon *et al.*, 2011). Various imaging modalities are used for mapping tumor induced tissue changes like T2 and FLAIR MRI which highlight the difference in tissue water relaxation properties, post gadolinium T1 MRI that shows pathological intratumoral take up of contrast agents, perfusion and diffusion MRI which localise the water diffusion and blood flow. These modalities provide different types of information and possess different processing tasks (Menze *et al.*, 2015). MRI has no known biological hazard and also it is capable of producing high resolution thin tomographic images in any plane and blocks of 3-dimensional information (Longmore, 1989). The three standard anatomical planes are axial, sagittal and coronal planes. Sagittal plane is any vertical plane parallel to the median plane. Coronal plane is a vertical plane perpendicular to the sagittal plane. Axial plane is perpendicular to both sagittal and coronal plane (Park *et al.*, 2010). The brain can be viewed in three perspectives, they are transverse (axial or x-y) planes, which slice the patient

from top to bottom where as sagittal (y-z) planes slice the patient laterally and coronal plane (x-z) slice the patient from front to back. In the brain MRI volume, axial, sagittal and coronal planes consist of two dimensional slices (Mahmoudzadeh and Kashou, 2014). MRI also provides detailed information which helps in differential diagnosis and management of brain lesions (Karpagam and Vadanika, 2015). Since MRI planes play an important role in imaging of brain lesions, the aim of the study is to characterize and identify the orthogonal imaging planes through comparison to detect brain tumor lesions.

Materials and Methods

This descriptive study was conducted in the Radiology Department of one of the major tertiary health care centres in South Kerala, India. Patients suspected of brain lesions and who underwent MRI for diagnosis was included in the study. Both males and females were included. Patients with the proven MRI diagnosis were only included as study subjects. Those with implants, aneurysm clips, pacemakers, heart valves and those who are not willing to participate in the study and patients with age below 20 years were excluded from this study.

MR imaging was done for 69 (n = 69) patients with different types of tumor lesions. Imaging was performed with a 1.5-T scanner and studied for their differential diagnosis through different planes (axial, coronal and sagittal) with a head coil of 30 cm diameter. The MR images were generated with the help of sophisticated combination of electronics, radiofrequency (RF) generators, coils, and gradients that interface with a computer for communication between the different electronics. This combination of equipment allows localization, excitation, and acquisition of a specific tissue of interest and formation of a digital image. The gradients perform three functions: slice selection (z component), frequency encoding (x component), and phase encoding (y component). The slice perpendicular to the z axis is called axial plane. The sagittal or median plane is the plane that divides the brain into left and right parts. The coronal plane is the vertical plane which divides the brain into posterior and anterior parts (Rajasekaran and Gounder, 2018).

All images were obtained by using spin-echo pulse sequences, gradient echo sequences; FLAIR and a two-dimensional Fourier transform image reconstruction. From all patients we obtained T1-wt spin-echo images (500-600/20-30/2-4 repetition time/echo time/excitations) and T2-wt spin-echo, FLAIR, gradient echo (2500-3000/30, 80/1), post gadolinium T1 MR, perfusion and diffusion MRI. The images were acquired on a 256x256 matrix, with a field of view of 23 cm. All images had a slice thickness of 5mm and the number of slices taken was 20. The MRI studies were evaluated for the volume of brain lesions on three different planes. A reference line was drawn as the longest tumor diameter anteroposteriorly on the axial view, mediolaterally on the coronal view, and superiorly inferiorly on the sagittal view respectively. Figure 1, 2 and 3 show brain lesion in axial plane, in sagittal plane and in coronal plane respectively for the same

tumor. Size of the brain lesions were measured including length and width. Nowadays tumor measurements can be assessed with highly accurate and reproducible measurements. Brain tumor scans can be automatically analyzed, providing enormous potential value for the improved diagnosis. The automated brain tumor segmentation techniques are

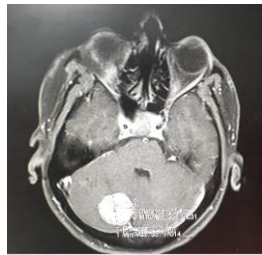


Figure 1. Brain Tumor in axial plane.

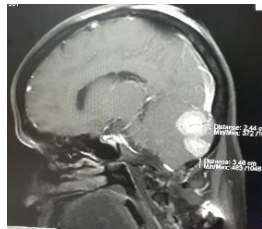


Figure 2. Brain Tumor in sagittal plane.



Figure 3. Brain Tumor in coronal plane.

technically challenging, as the lesion areas are only defined through intensity changes. Even manual segmentations shows variations when intensity gradients between adjacent structures are smooth or obscured by partial voluming or bias field artifacts. Moreover the tumor structures vary across patients in terms of size, extension and localization. (Menze *et al.*, 2015). Similarly another technique for Radiologist, to maintain a high level of detection, sensitivity as well as reducing image reading time, is computer-aided detection (CAD) (Amboina *et al.*, 2010). However within the limitations of the available facilities mentioned above (automatically analyzed technique), in our setup, the volume is calculated manually. Volume was calculated by using the formula (Kanazawa *et al.*, 2017),

$$\text{Volume} = \frac{\text{Area of the brain lesion} \times \text{slice thickness}}{\text{Number of slice}}$$

Brain tumor lesions (n = 69) were categorized as 9 groups (group I, II, III, IV, V, VI, VII, VIII and IX) depending on the volume dimension of the tumor lesion. Group 1 (n = 10) indicates the dimensions from 0.5 mm to 2 mm where as group II (n = 17) gives the dimensions from 2.5 mm to 4 mm. Group III (n = 4) from 4.5 mm to 6 mm, group IV (n=12) from 7 mm to 9.5 mm, group V (n = 6) from 10.5 mm to 11.75 mm, group VI (n = 5) from 14 mm to 16.5 mm, group VII (n = 3) gives 16.6 mm to 20 mm, group VIII (n = 5) 19 mm to 22 mm and group IX (n = 7) from 33 mm to 35 mm respectively. The variations in the volume of the anatomical structures were measured and compared the planes as axial/sagittal, axial/coronal and coronal/sagittal.

Statistical Analysis was done by SPSS version 16 software. The quantitative variables were expressed in mean and standard deviation (SD). Two way/Friedman Test were used for comparing the three groups.

Table 1. Age Distribution of Brain tumor lesion patients.

Sl No	Age Distribution Types of Lesions	Age		
		<40 years	40-60 years	>60 years
1	Meningioma	0	7	12
2	cerebellopontine	0	5	4
3	Metastasis	0	5	3
4	Lymphoma	0	2	4
5	Glioblastoma	0	2	4
6	Adenoma	0	2	4
7	Glioma	0	1	3
8	Oligodendroglioma	0	3	1
9	Subependymoma	0	1	3
10	Tuberculoma	1	1	1
	Total	1	29	39

Ethics Approval

The study was approved by the Institutional Ethics Committee of Sree Gokulam Medical College and Research Foundation (SGMC-IEC No: 31/383/11/2018). Written informed consent was obtained from each participant.

Results and Discussions

MRI images of 69 brain tumor lesions were studied and compared for three planes (axial, sagittal and coronal). In this study the brain tumors (n = 69) like lymphoma, meningioma, cerebellopontine angle tumor, subependymoma, tuberculoma, macroadenoma, microadenoma, metastasis, glioma, oligodendroglioma and glioblastoma were included. Table 1 and Table 2 shows the demographic datas of brain tumor lesion patients including age distribution and gender distribution. The age varied from younger age group (<40), middle age group (40 to 60 years) and old age group (>60 years). The result shows that among 69 cases, the brain tumor lesions was higher (39) in older age group than middle age (29) and younger age group (1). Table 2 gives the gender distribution. Among these 69 cases, present study indicates that brain tumor lesions were more common in males (37) than females (32). Table 3 shows the average volume measurement of tumors

which are grouped into I to IX. The results show that among the different groups of tumors, the volume of axial planes is measured as larger volume than the sagittal and coronal planes.

It was found that in group I, there was a statistically significant difference in measured volume depending on the plane, $\chi^2(2) = 7.800$, $p = 0.02$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) of volume measured by axial, sagittal and coronal planes were 1.71 (0.98), 1.4 (0.76) and 1.3 (0.55), respectively. There were no significant differences between volumes measured by sagittal and coronal planes ($Z = -0.067$, $p = 0.502$) or between sagittal and axial ($Z = -2.012$, $p = 0.044$) planes. However, there was a statistically significant difference between the volume measured by coronal and axial planes ($Z = -2.683$, $p = 0.007$). Tumor group II shows that Median (IQR) of volume measured by axial, sagittal and coronal planes were 3.57, 3.42, and 3.69 respectively. There were no significant differences between volumes measured by sagittal and coronal planes ($Z = -1.972$, $p = 0.049$) or between coronal and axial ($Z = 0.686$, $p = 0.493$) planes. However, there was a statistically significant difference between the volume measured by sagittal and axial planes ($Z = 2.658$, $p = 0.008$). In Group III, Median (IQR) of volume measured by axial, sagittal and coronal planes were 5.32, 5.23 and 4.80 respectively. There were no significant differences between volumes measured by axial, sagittal and coronal planes and there is no significant difference between the planes ($p = 0.368$). Group IV shows that Median (IQR) of volume measured by axial, sagittal and coronal planes were 7.73, 8.50 and 7.20 respectively. There were no significant differences between volumes measured by sagittal and coronal planes ($Z = 2.041$, $p = 0.041$) or between sagittal and axial ($Z = 0.816$, $p = 0.414$) planes. But there was a statistically significant difference between the volume measured by coronal and axial planes ($Z = 2.858$, $p = 0.004$). Tumor group V shows that Median (IQR) of volume measured by axial, sagittal and coronal planes were 11.12, 10.86 and 10.43 respectively. There were no significant differences between volumes measured by sagittal and coronal planes or between sagittal and axial or between coronal and axial planes ($p = 0.119$). Group VI shows that Median (IQR) of volume measured by axial, sagittal and coronal planes were 15.0, 14.81 and 14.87 respectively. There were no significant differences between volumes measured by sagittal and coronal planes or between sagittal and axial planes and between the volume measured by coronal and axial planes ($p = 0.119$).

Table 2. Gender Distribution of Brain tumor lesion patients.

SL No	Gender Distribution Types of Lesions	Gender	
		F	M
1	Meningioma	12	7
2	cerebellopontine tumor	4	5
3	Metastasis	3	5
4	Lymphoma	2	4
5	Glioblastoma	2	4
6	Adenoma	3	3
7	Glioma	3	1
8	Oligodendroglioma	1	3
9	Subependymoma	1	3
10	Tuberculoma	1	2
	Total	32	37

Table 3. Tumor- average volume measurements of MRI orthogonal planes.

Tumor-average volume measurements of MRI orthogonal planes				
Sl No	Groups	Axial	Sagittal	Coronal
1	I	1.4982	1.2232	1.1975
2	II	3.656	3.379	3.618
3	III	5.368	5.143	4.862
4	IV	8.037	7.8	8.044
5	V	11.166	10.952	10.52
6	VI	15.279	14.879	15.169
7	VII	19.65	18.36	16.95
8	VIII	21.167	20.516	20.327
9	IX	35.63	35.32	35.217

Tumor group VII shows that Median (IQR) of volume measured by axial, sagittal and coronal planes were 19.95, 18.05 and 16.65 respectively. There were no significant differences between volumes measured by sagittal and coronal planes, between sagittal and axial planes and ($p = 0.05$) between the volume measured by coronal and axial planes. Tumor group VIII and IX shows that there were no significant differences between volumes measured by sagittal and coronal planes, between sagittal and axial planes and between coronal and axial planes ($p = 0.165$) and ($p = 0.066$).

Discussion

Through this study we investigated and analyzed the different types of tumor lesions having different dimensions in MRI images of patients. Our data shows that in MRI images, the tumor lesions like lymphoma, tuberculoma, meningioma, cerebellopontine angle tumor, subependymoma, adenoma, metastasis, glioma, oligodendroglioma and glioblastoma were more superior in axial planes than in sagittal or coronal planes. Present study revealed that in macroadenoma, the morphology shows as suprasellar mass and was diagnosed as superior in axial MRI planes (Table 3, group 1, 3, 6, 5) than the sagittal and coronal planes. In one of the study, it was found that macroadenoma was appeared as a large mass in MRI axial images, where as the coronal and sagittal images gave only a moderate enhancement (Chaudhary and Bano, 2011). Present study also revealed that the tumor lesion like glioblastoma was seen as aggressive mass was observed very clearly as their volume dimensions were more in axial (Table 3 group 1, 4, 9) when compared to sagittal and coronal images. Similarly another study also clarified that the mass lesion of glioblastoma is well defined in axial image (Mabray *et al.*, 2015). This study also shows that both large and small tumors are easily diagnosed in MRI images. The previous studies also found that MRI is a very good modality to detected small tumors, and also large tumors. In addition to that it was also found that the tumors <5 mm in diameter can be reliably identified and the intratumoral degenerative changes in large tumors may result in an increase in heterogeneity of signal. It was also found that on axial images, the tumors were seen as homogeneous contrast enhancement (Yadav *et al.*, 2015).

Studies also mentioned that the accurate assessment of brain tumors were difficult in clinical trials because of the usage of different methods (Shah *et al.*, 2006). In this study it was found that the size of the tumor can be measured through MRI

planes and is useful for both in diagnosis as well as prognosis. Previous studies show that, the measurement of tumor size on images is very important both clinically and therapeutically as the brain tumors are not palpable or otherwise amenable to physical examination and also the change in size cannot be estimated from neurologic examinations or assessments of function (Provenzale *et al.*, 2009). The present study gives a better diagnostic image in the case of meningioma in axial plane (Table 3 group 1 to 9) of MRI than in sagittal and coronal planes and it was morphologically viewed as intracranial neoplasm. In one of the study it was reported that in case of meningioma, the axial image showed intraoral mass with smooth dural thickening and enhancements. Similarly they also found that another axial image diagnosed as homogeneously enhancing mass within the right lateral ventricle was also observed as meningioma (Watts *et al.*, 2014). In another study also, it was found that MRI image shows a well circumscribed meningioma in axial T2 wt image (Lyndon *et al.*, 2019).

It was found from the study that the axial images of oligodendroglioma (Table 3 group 2, 9) can be diagnosed more easily than the sagittal and coronal images as their volume is more compared to other planes and was composed of neoplastic oligodendrocytes. Studies also revealed that the MRI axial image of oligodendroglioma gave a high signal and mass effect when compared to CT image (McKean *et al.*, 2015). It was found that the metastasis as neoplasm and the volume of brain metastasis in axial plane (Table 3 group 2, 3, 4) is better than sagittal and coronal planes. In another study it was found that the axial planes showed clear images on both pre and post contrast MRI images of both 1.5T and 7T of MRI images of metastatic brain tumor (Paek *et al.*, 2013). It is also reported that a contrast enhanced axial image was diagnosed clearly in the tumour subependymoma, size ranged from 1.5 cm to 7.3 cm (Hou *et al.*, 2012). Present study also revealed a clear mass of cerebellopontine angle tumor observed in axial (Table 3 group 1, 2, 3, 4, 5, 6, 7, 9) imaging plane than sagittal and coronal planes. Similarly in one of the studies it was found that the preoperative axial image demonstrates a clear mass in the left cerebellopontine angle tumor (Gao *et al.*, 2015) and it was viewed at the margin of cerebellum and pons. In this study it was found that the glioma (Table 3 group 1, 2) is observed as a clear image on axial plane of MRI than in sagittal and coronal planes and viewed as necrosis. In another study it was reported that the high grade glioma in MRI axial image demonstrated intracranial mass with edema (Lavra *et al.*, 2017), again supporting our findings.

Conclusion

The development of magnetic resonance imaging (MRI) used in medical investigation has provided a huge forward leap in the field of diagnosis particularly with avoidance of exposure to potentially dangerous ionizing radiations. With decreasing costs and better availability, the use of MRI is becoming ever more pervasive throughout clinical practice. MRI imaging modality and its multiple applications can be used to appreciate the benefits for further informing clinical decision-making. In this article, the importance of MRI planes in diagnosis of tumor lesions were studied and found that the volume of brain lesions diagnosed in axial planes are more superior than sagittal and coronal planes which will help in the proper diagnosis of brain lesions and subsequent treatment.

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