Original Research Article

DIFFUSION WEIGHTED MRI: ROLE IN THE DIFFERENTIAL DIAGNOSIS OF SPACE OCCUPYING BRAIN LESIONS

Dr. Harsha Singh[1] (Resident), Dr. Indra Kumar Batham[2] (Associate Professor), Dr. Ratnesh Jain[3] (Associate Professor), Dr. Akshara Gupta[4] (Professor and Head) & Dr. Sweta Swaika[5] (Assistant Professor)

Department of Radio-Diagnosis, GRMC and JAH Gwalior, 474009, Madhya Pradesh, India[1,2,3,4&5]

Corresponding Author: Dr. Indra Kumar Batham

Abstract

Aim and objective: To use Diffusion-weighted MRI to evaluate and differentiate space-occupying brain lesions in individuals whose conventional MRI (cMRI) assessment revealed aberrant imaging characteristics suggestive of space-occupying brain lesions.

Material and Method: We conducted prospective, observational study which enrolled 100 patients had different space occupying lesion detected with DWI. The study was performed on a whole body system at 1.5 Tesla MRI, using a dedicated head coil. Multiplanar T1- and T2-weighted, diffusion, gradient images, using spinecho sequences, post contrast study, and proton magnetic resonance spectroscopy were performed in all cases on single and multivoxels chemical shift imaging. All cases were correlated with histopathology and by follow-up studies after management.

Results: Study was done for a period of 1-year in patients of varying clinical symptoms subjected for MRI. Male subjects were more than females. 65% had intra axial whereas 35% had extra axial lesion among space occupying lesion. Abscess highly observed in intra axial whereas meningioma highly observed in extra axial lesions. In our study, tumors, infection, cystic lesions and demyelination type of etiology observed among patients. Tumors were most common overall etiology in our study.

Conclusion: Diffusion-weighted magnetic resonance is a useful imaging technique that helps in preoperative differential diagnosis of various space occupying lesions which helps in precise diagnosis and improves the prognosis of many patients with space-occupying lesions.

1. INTRODUCTION

Intracranial space occupying lesions (ICSOLs) are any lesions that take up space in the intracranial fossa and generate increased intracranial pressure. A lesion that occupies cerebral space can be malignant, infective, inflammatory, vascular, or traumatic. Because of the increased intracranial pressure, the lesion might generate broad symptoms such as seizures or false localizing indications, localized brain injury, or obstruction of cerebrospinal fluid flow. Because of their high morbidity and mortality, they must be diagnosed early and treated as soon as feasible [1].

MRI is now widely used to identify tumor extent for surgical and radiation planning, as well as post-therapy monitoring of tumor recurrence or advancement. MRI can offer an initial diagnosis of a cerebral mass lesion with a success rate of 30–90% depending on the

kind of tumor [2,3]. However, biopsy is still widely regarded as the gold standard for diagnosing the kind and extent of cancer [4].

It is crucial for clinicians to distinguish between brain infections and brain tumors because their treatment plans and prognoses are radically different (abscesses from necrotic or cystic brain tumors and encephalitis from diffuse gliomas, for example). Unfortunately, both radiologists and neurologists still have trouble diagnosing this distinction. It has been demonstrated that conventional MRI (cMRI) has only 61.4 percent sensitivity when used as the primary differential diagnosis to distinguish brain cystic neoplasms from abscesses [5,6]. Before starting treatment for cystic brain lesions, a precise diagnosis of the condition must be made because the medical management tactics for abscess and neoplasms differ. Neurosurgeons can choose the best course of action by understanding the precise nature of the lesion. For instance, cerebral abscess can be aspirated stereotactically and then treated with intravenous antibiotics, avoiding the need for a craniotomy [7,8] and lowering the morbidity and mortality associated with a delayed diagnosis [9].

It is possible to evaluate the diffusion characteristics of water molecules in brain tissues that may be significantly affected by illnesses using diffusion-weighted imaging (DWI). True diffusion, according to Fick's law, is the net movement of molecules as a result of a concentration gradient. With MRI, it is impossible to distinguish between molecular motion brought on by pressure gradients, temperature gradients, or ionic interactions. Therefore, only the apparent diffusion coefficient (ADC) may be computed when monitoring molecular mobility with DWI [10]. It has been applied to research both healthy brain function as well as a number of illnesses, including ischemia, tumors, epilepsy, and white matter abnormalities [11–13].

When differentiating and grading brain tumors, computed ADC values from the centre of the lesion provide additional information to MRI [14]. DWI can be used to distinguish brain lymphoma from high-grade glioma (astrocytoma) and butterfly glioblastoma multiforme in cases of brain malignancies [15]. Pediatric posterior fossa cancers, especially medulloblastoma, fourth ventricular ependymoma, and juvenile pilocytic astrocytoma, are successfully distinguished with DWI [16]. If both MR spectroscopy and DWI are used, it may be possible to avoid the necessity for a biopsy.

Calculated ADC values can be utilised to recognise brain abscesses and help distinguish them from cystic brain tumors (such as cystic gliomas, brain metastases) and nontumor ring-enhancing brain lesions (such as tumefactive multiple sclerosis) [17]. DWI is a fantastic technique for separating epidermoid from arachnoid cysts, which can occasionally be difficult with cMRI [18].

Only brain imaging investigations can accurately establish the diagnosis of cerebrovascular stroke and distinguish between haemorrhage and ischemia, despite the fact that patient symptoms and clinical examinations may also point to this possibility. At the same time, DWI shown advantages in defining ischemic pathophysiology and was useful in characterising intracerebral haemorrhage [19].

2. MATERIAL AND METHODS

This prospective and observational study was carried out over a period of 1 year from June 2021 to June2022. The study was approved by the Institutional Ethical Clearance Committee and has followed the tenets of the Declaration of Helsinki. Patients of all age group presenting with ICSOLs which were confirmed by magnetic resonance imaging (MRI) and treated surgically in our institute were included in this study. Patients who had received

chemotherapy or radiotherapy before surgery or with coexistent primary neoplasm elsewhere were excluded from the study. Patients related demographic parameters, etiology , type of lesion were recorded in our study.

Method of evaluation

Patient undergone MRI scan, Conventional MRI findings noted. DWI and ADC values calculated Correlating and comparing the results of both the techniques. Multiplan and multisequential scan of the brain in a 1.5 tesla. The following are acquired on a conventional imaging sequences, pre-contrast: Axial, Sagittal and coronal T1 WI [550/15ms (TR/TE)] spin echo, axial and coronal T2 WI (3000/120ms) turbo spin-echo, and fast fluid attenuation inversion recovery (FLAIR) [8000/140/2800ms (TR/TE/TI)]. Post-contrast series included axial, coronal and sagittal T1 WI spin echo sequences. For diffusion-weighted imaging, following sequences are acquired: DWI will be performed in the axial plane using single shot echo-planar spin-echo sequence EPI [3435/89cms (TR/TE)], matrix 128 x 128, slice thickness 5 mm, gap 1 mm with duration of 30s, and b = 0 and b = 1000 applied in X and Y directions. Post processing of ADC maps will be done using the standard software supplied on the machine console to obtain the ADC value and map.

MRI protocol

MRI protocol consisted of the following parameters:
1) A head coil was used
2) Axial diffusion weighted images of the brain
3) Sagittal and axial T1W images of the brain
4) Sagittal and axial T2W and FLAIR images of the brain 5)Sagittal and axial post-GAD T1W images of the brain
6) ADC images were reconstructed from the diffusion weighted image

Statistical Analysis:

Data was analyzed using SPSS, version 26.0 (SPSS Inc., Chicago, IL, USA). Quantitative data was expressed as mean ±SD whereas qualitative data was expressed in percentage by using SPSS. Comparisons between the groups were done using independent t test wherever appropriate. A p value <0.05 was considered statistically significant.

3. OBSERVATION AND RESULTS

The present study is a prospective comparative study conducted in Department of Radio diagnosis, at our institute. A total of 100 patients were selected out of those presenting with space occupying lesions between June 2021 to June2022 and evaluated in this study. Observations were made based on clinical history and MRI findings of the patient.

Demographic Characteristic

Out of 100 patients, 25% of patients were observed in the 41–50 age group, whereas the least number of patients was observed in the >70 age group (2%). Another age group of patients included: 1) 21-30 (18%), 31-40 (15%), 61-70 (13%), 0-10 (11%), 51-60 (10%), and 11-20 (6%). In our study population, 25% had major part cover in the 41–50 age group, whereas 2% had minimum part cover in the >70 age group. We found that paediatric patients aged <1 to 10 years also have space-occupying lesions.63% had males whereas 37% had females were observed in our study.(p=0.0002).

According to our study, the highest percentage was observed in the 41–50 age group, whereas the least percentage was observed in the >70 age group. Most of the females were in the age group between 21 and 40, whereas most of the males were observed in the 41–50 age group. We observed that space-occupying lesion also observed in pediatric patients age <1-10 years.

Graph 1: Histogram of age and gender wise distribution
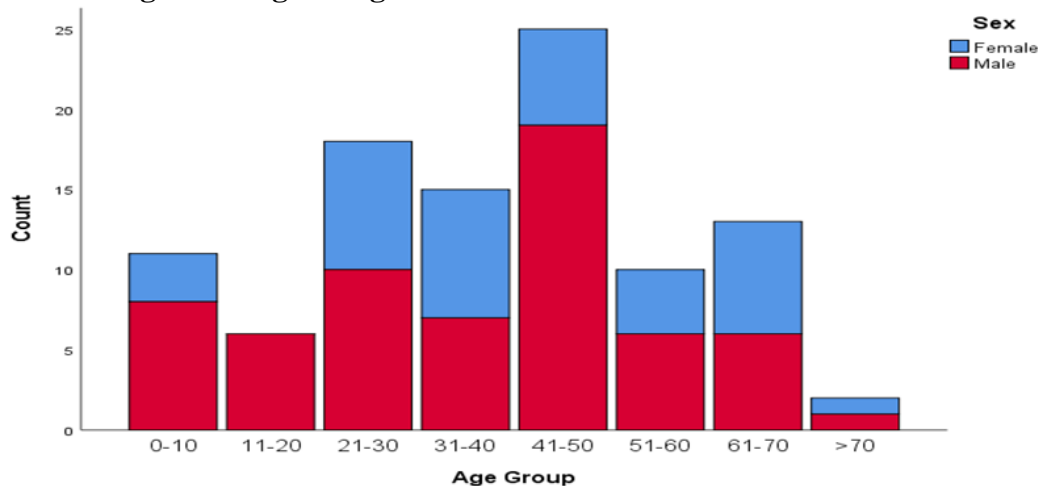
**Graph 2: Age Distribution**
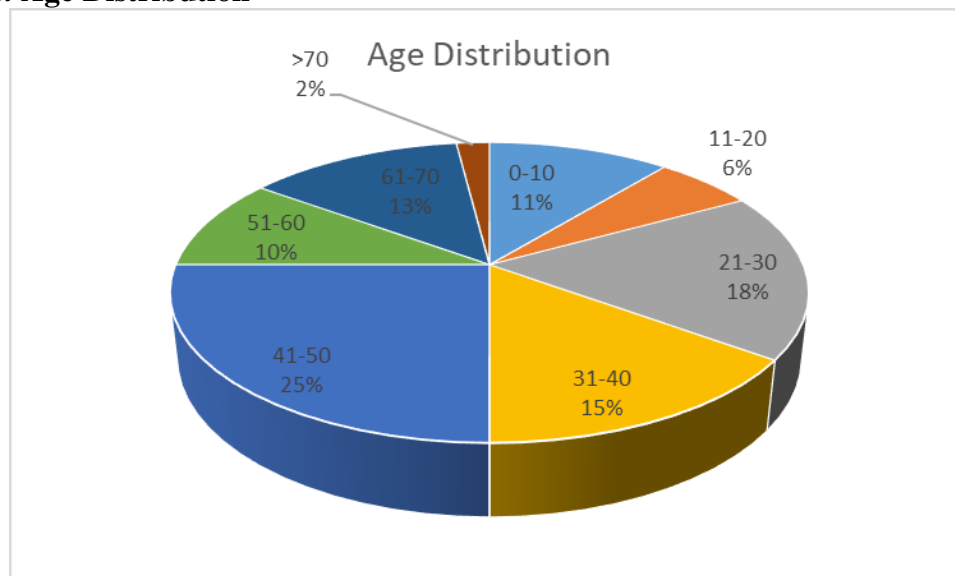
Intra and Extra Axial lesions

We identified 65% of the 100 different space-occupying lesions to be intra axial, while 35% of patients had extra axial location. Out of 100 patients, 65 patients have intra-axial and 35 patients have extra-axial tumors. Patients with Intra axial tumor had mean age of 36.20 ± 20.26 years, whereas patients with extra axial had mean age of 44.20 ± 15.42 years.

Intra axial and extra axial are part of a location-based space-occupying lesion. The following intra-axial lesions were discovered by us: : Abscess (20%), metastasis (18.5%), and tuberculoma (15.4%), low grade glioma (12.3%) , Encephalitis (12.3%),Lymphoma (6.2%),
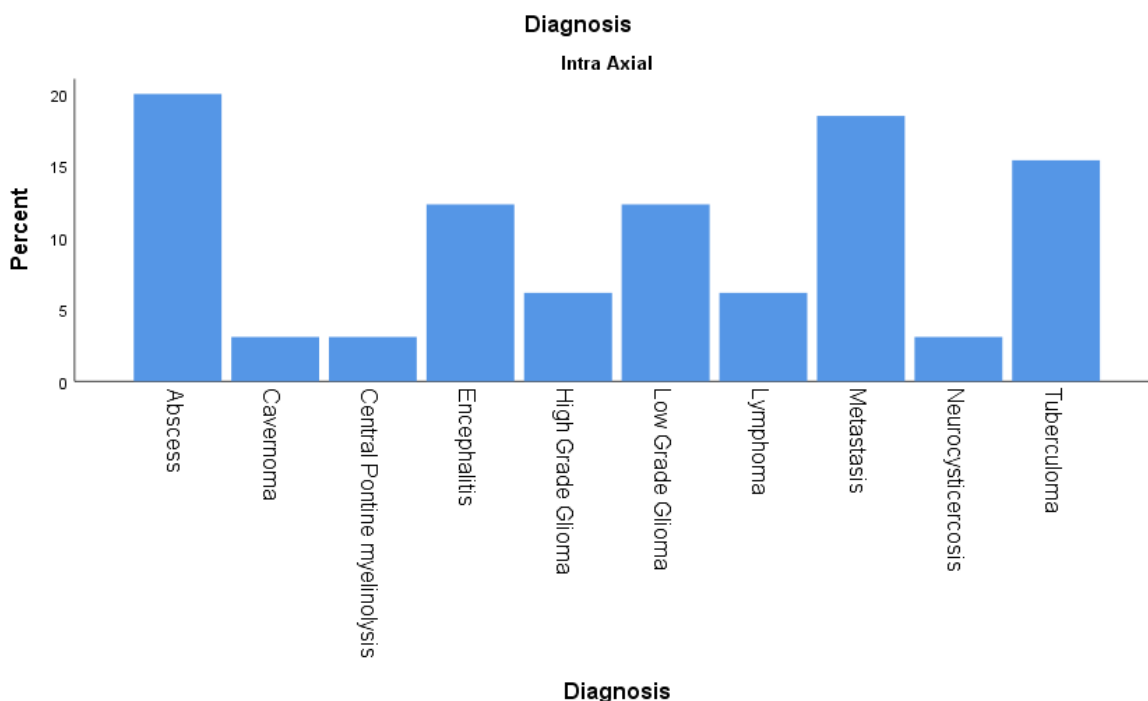
High grade glioma (6.2%), Neurocysticercosis (3.1%), Central Pontine myelinolysis (3.1%) and Cavernoma (3.1%).

In the extra axial location of the space-occupying lesion, we observed cases as followings: Meningioma (37.1%), Schwannoma (28.6%), Arachnoid Cyst (17.1%) and Epidermoid Cyst (17.1%).
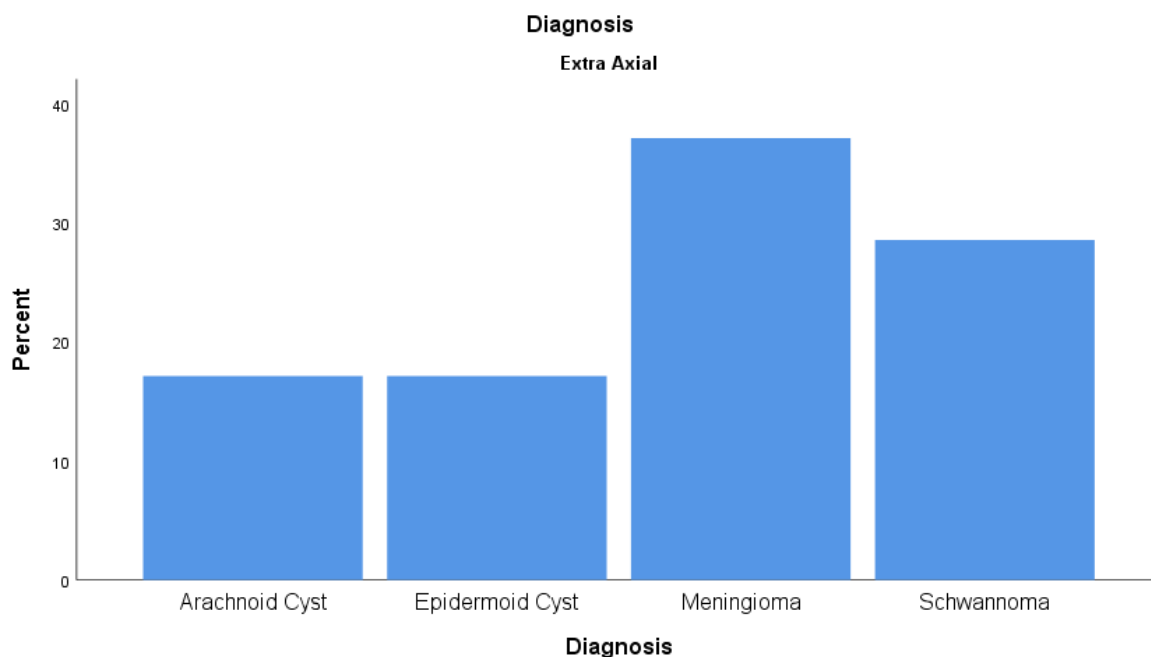
Graph 3: Location wise distribution
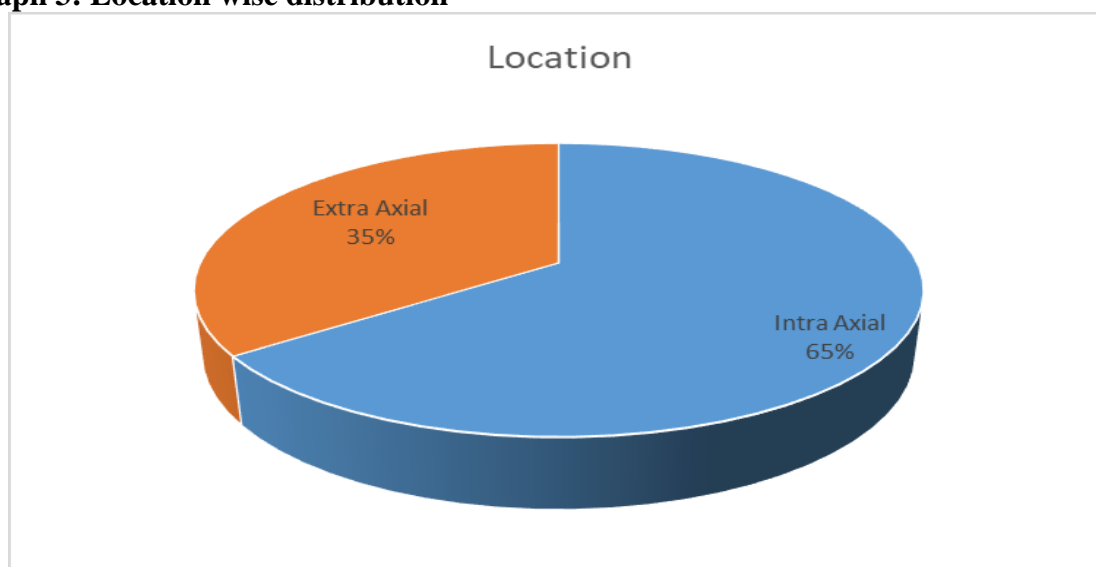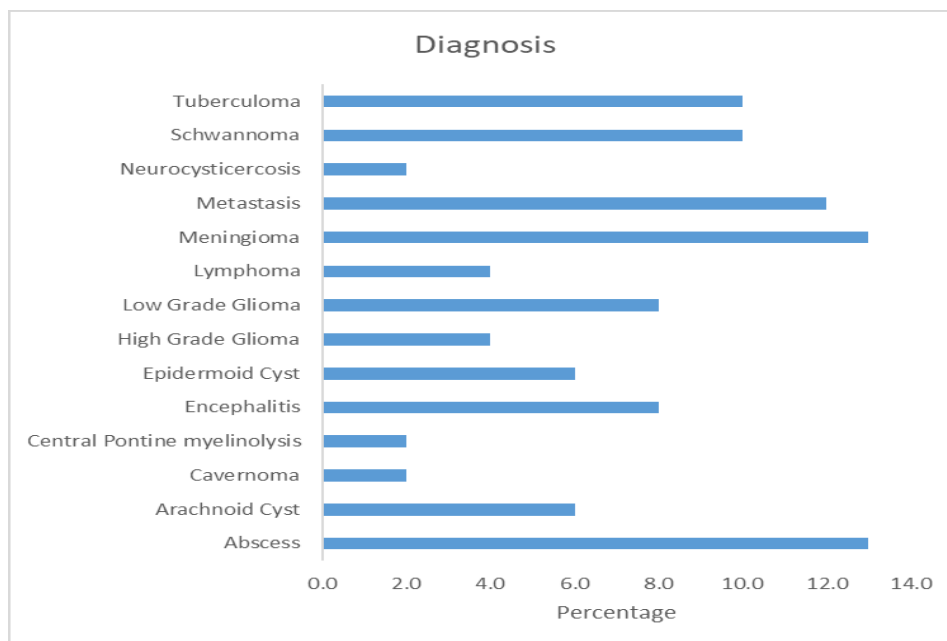

Graph 4: Intra axial location
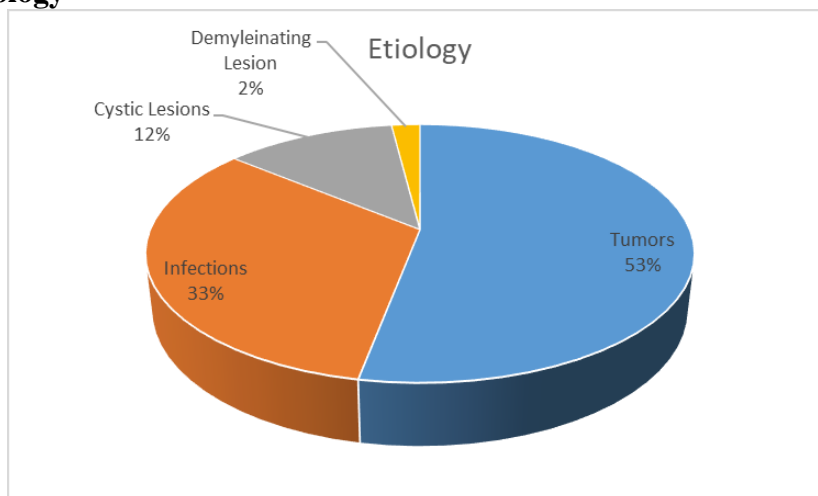
Graph 5: Extra axial location

Etiology

We observed the following types of aetiology in our study group: tumors (53%), infections (33%), cystic lesions (12%) and demyelinating lesions (2%). In our study, tumor aetiology was highly observed, whereas the minimum cases observed were related to demyelinating lesions (2%).

Graph 6 : Different diagnosis

Graph 7: Etiology

Table 1: Etiology

	Frequency	Percent
Abscess	13	13.0
Arachnoid Cyst	6	6.0
Cavernoma	2	2.0
Central Pontine myelinolysis	2	2.0
Encephalitis	8	8.0
Epidermoid Cyst	6	6.0
High Grade Glioma	4	4.0
Low Grade Glioma	8	8.0
Lymphoma	4	4.0
Meningioma	13	13.0
Metastasis	12	12.0
Neurocysticercosis	2	2.0
Schwannoma	10	10.0
Tuberculoma	10	10.0
Total	100	100.0

Gender wise intra and extra axial lesion

Gender-based age group, we did not observe a significant relationship between the two groups. (t=1.60, p=0.112,) (Mean difference (95% confidence interval) = 6.27 (-1.49, 14.03)). Therefore, we could say that the female and male age groups equally distributed in our study group.

Location wise intra and extra axial lesion

In location-based age groups, we observed a significant relationship between intra-axial and extra axial. (t = -2.04, p=0.044)(Mean difference (95%CI) = -8.00 (15.80, -0.21)). Therefore, we could say that intra-axial location has a highly observed lower age group compared to extra-axial location.

DWI/ADC features

According to DWI/ADC features, No DWI Restriction / High ADC Signal observed in 53% whereas DWI Restriction / Low ADC Signal observed in 47 %.

Table 2: Provisional Diagnosis on Conventional MR Sequences

Sr. No	Provisional Diagnosis on Conventional MR Sequences	DWI/ADC features
1	Abscess	DWI Restriction / Low ADC Signal
2	Arachnoid Cyst	No DWI Restriction / High ADC Signal
3	Cavernoma	No DWI Restriction / High ADC Signal
4	Central Pontine myelinolysis	DWI Restriction / Low ADC Signal
5	Encephalitis	DWI Restriction / Low ADC Signal
6	Epidermoid Cyst	DWI Restriction / Low ADC Signal
7	High Grade Glioma	Variable DWI Restriction / Variable ADC Signal
8	Low Grade Glioma	No DWI Restriction / High ADC Signal
9	Lymphoma	DWI Restriction / Low ADC Signal
10	Meningioma	No DWI Restriction / High ADC Signal
11	Metastasis	Variable DWI Restriction / variable ADC Signal
12	Neurocysticercosis	No DWI Restriction / High ADC Signal
13	Schwannoma	No DWI Restriction / High ADC Signal
14	Tuberculoma	DWI Restriction / Low ADC Signal

4. DISCUSSION

Image contrast offered by diffusion-weighted MRI is distinct from that of traditional MRI sequences. It offers a method for mapping proton contrast that takes into account the microvascular setting. This imaging method is susceptible to ischemia injury that occurs early. A pulse sequence used for DWI can measure the translation of water over relatively short distances. Compared to the normal brain, several disease circumstances cause this water diffusion to be substantially slower.[20]

In order to examine water mobility in brain tissue and to characterize intracranial space-occupying lesions, MR diffusion imaging is a crucial technique. Because multiple therapy modalities and prognoses exist, preoperative classification of brain mass lesions is crucial. [21]

100 patients with intracranial mass lesions found on brain MRI were included in this investigation. It was discovered that DW MRI, in addition to conventional MRI, gives supplemental information for cerebral mass lesions, including infections, intra-axial, and extra-axial lesions. [22].

Tumors (53 cases), infections (33 cases), cystic lesions (12 cases), and demyelinating disease (2 cases) are the four main groupings of patients.

Out of 100 patients, 63 (63%) were males and 37 (37%) were females. The mean age among Females was 42.95 ± 18.84 years and the mean age among males was 36.68 ± 18.89 years. Out of 100 patients, 65 (65%) were diagnosed to have intra axial lesions and 35 (35%) to have extra axial lesions. Of the 100 patients included in this study, 47 cases (47%) showed hyper intensity on DWI of which true restriction (hyper intense on DWI and hypo intense on ADC). T2 shine through was noted in 41 patients (41%). 40 patients (40%) showed T2

washout (isointense on DWI). 18 patients (18%) showed no signal change on DWI or ADC images. Gupta et al., 2022 also found similar results to our study.[23]

The study included 33 infective conditions of which 13 (13%) were Abscess, 8 (8%) were Encephalitis, 2(2%) were Neurocysticercosis and 10 (10%) was Tuberculoma. T2 shine through was seen in both Tubercular and NCC granuloma.

GT Santoset et al. [24] investigated 48 patients with NCC retrospectively in 2012 and established that DWI may identify the scolex, enhancing diagnostic confidence for NCC. Although total/subtotal DWI hyperintensity related to lesion stage is unusual, it permits NCC to be considered in the differential diagnosis of lesions with reduced diffusion and ring enhancement, where 2% was observed in our sample. Encephalitis affected 8% of the people in our study. They concluded that DWI is superior to other conventional diagnostic MR sequences in detecting early viral encephalitic lesions and depicting lesion borders, and that when combined with other sequences, DWI may contribute to disease phase identification. Serner RN.[25] concluded in another investigation that diffusion imaging appears to be a promising sequence for monitoring changes in brain tissue in viral encephalitis. MR imaging is the most sensitive means of detecting brain tumors. It is, however, insufficiently specific to detect the histological nature of the majority of tumors.[26].

When it comes to imaging diagnosis, care, and monitoring, brain abscesses and necrotic tumors require different approaches. It is difficult for standard MRI to discriminate between brain abscesses and necrotic tumors, so new and more techniques that are sophisticated are desperately needed. Brain abscesses can occasionally be identified using diffusion-weighted MRI. According to Desprechins et al. [27], differential diagnosis can be made using a high signal intensity in diffusion imaging and a noticeably reduced apparent diffusion coefficient.

Low viscosity and free molecular diffusion in the cystic or necrotic region of the brain tumor cause a high ADC. In contrast, pus, a reddish brown viscous fluid made up of inflammatory cells, bacteria, necrotic tissue, and proteinaceous extruded plasma with a very high viscosity and cellularity, fills the centre chamber of an abscess, leading to a significantly lower ADC. This discovery might facilitate preoperative differentiation between necrotic tumors and abscesses. DWI aids in the characterization and grading of tumors by helping to distinguish between a tumor and an infection and by providing data on the cellularity of the tumor. [28] Abscesses accounted for 13% of the patients in our research sample. Abscesses are thought to be caused by the presence of inflammatory cells, bacteria, and pus. Chang et al.[29] published a study on diffusion-weighted MRI findings of brain abscess in 2002.

Our study included 30 cases of intra-axial tumors. There were 12 females and 18 males in the group. There were four cases of high-grade glioma, eight cases of low-grade glioma, four lymphomas, twelve metastases, and two cases of cavernoma. Cruz CH et al. shown that highly cellular tumors with restricted diffusion, such as high-grade gliomas and lymphomas, can have low ADC values. [30,31]

In total, 23 cases of extra axial tumors were included in this study. Of these, 12 were females and 11 were males. There was no diffusion restriction in all 23% of the cases of extra axial tumors. These were 13 cases of meningioma and 10 cases of schwannoma. When comparing vestibular Schwannomas and meningioma, the signal intensity on T2W is higher in the vestibular Schwannomas. Signal heterogenicity is common in vestibular Schwannomas than in meningioma, also found in Gupta et al., 2022. [23]

The study covered 12 cystic lesion conditions (12%), including 6 arachnoid cysts and 6 epidermoid cysts. There were 9 male and 4 female among the 12 extra axial lesions. On conventional MR sequences, there was no discernible difference between epidermoid and

arachnoid cysts. The interior architecture of epidermoid cysts, which is generally formed of desquamated epithelial keratin and cholesterol crystals, contributes to their significantly low ADC values. Another study conducted in 2001 by Bergui M et al. [32] titled "Diffusion Weighted Images of Intracranial Cystic like Lesions" established that diffusion restriction is shown by epidermoid cysts but not by arachnoid cysts, and diffusion weighted imaging can be used to differentiate between the lesions. In the study of Kohal GA et al., 2022, we observed comparable results. [33] Diffusion weighted MR is useful in distinguishing arachnoid cysts from epidermoid cysts. Schaefer et al. demonstrated that conventional MR could not be utilised to reliably distinguish these two lesions since they both have CSF-like signal intensity on conventional MR sequences. On DWI, however, the epidermoid cyst exhibits restricted diffusion, whereas the arachnoid cyst exhibits CSF-like intensity. [34]

Only two cases of demyelinating illness demonstrated diffusion restriction. Our study correlated well with previous studies done by Ruzek et al. [35] in 2004 and Rueda-Lopes FC et al. [36] in 2004, which showed that cases of central pontine myelinolysis showed restricted diffusion in the central pons within 24 hours of the onset of tetraplegia before the signs manifested at conventional imaging. Both incidences of central pontine myelinolysis were in men.

We propose that quantitative DWI would help better in the evaluation of intracranial lesions rather than a simple visual impression of restriction or no restriction.

5. CONCLUSION

- Etiology based differentiation could be helpful with the help of Diffusion weighted magnetic resonance. DWI is perfect in differentiating between tumors, infection, cystic lesions, and demyelination disease in space-occupying lesions. We were also able to tell the difference between intra-axial and extra axial space-occupying lesions and their parts.
- The ADC values among the intracranial lesions varied greatly, according to diffusion-weighted imaging. High-grade gliomas exhibit diffusion restriction and have lower ADC values than low-grade gliomas. It has also been used extensively in the diagnosis of a wide range of diseases, such as distinguishing between arachnoid cysts and epidermoid cysts and separating abscesses from cystic necrotic tumors.
- The diagnosis, subsequent therapy strategy, and follow-up of space-occupying lesions can all be aided by diffusion imaging. This may have a significant prognostic impact and may directly impact patient management strategies. As a result, it contributes to better patient care. This procedure should not replace histology; it should be utilized in addition to it.

REPRESENTATIVE IMAGES
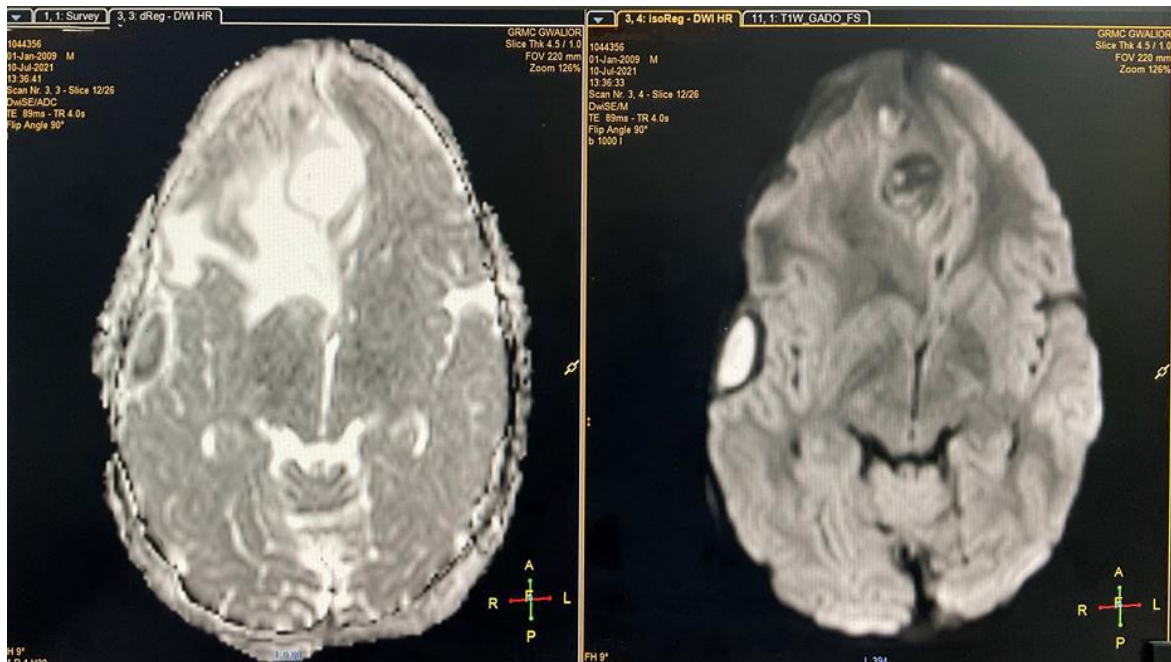
Figure 1: An extra axial lesion noted in right frontoparietotemporal lobe showing DWI restriction, another similar intraaxial lesion noted in right basifrontal region showing DWI restriction with significant perilesional edema suggestive of intraparenchyma abscess with subdural empyema
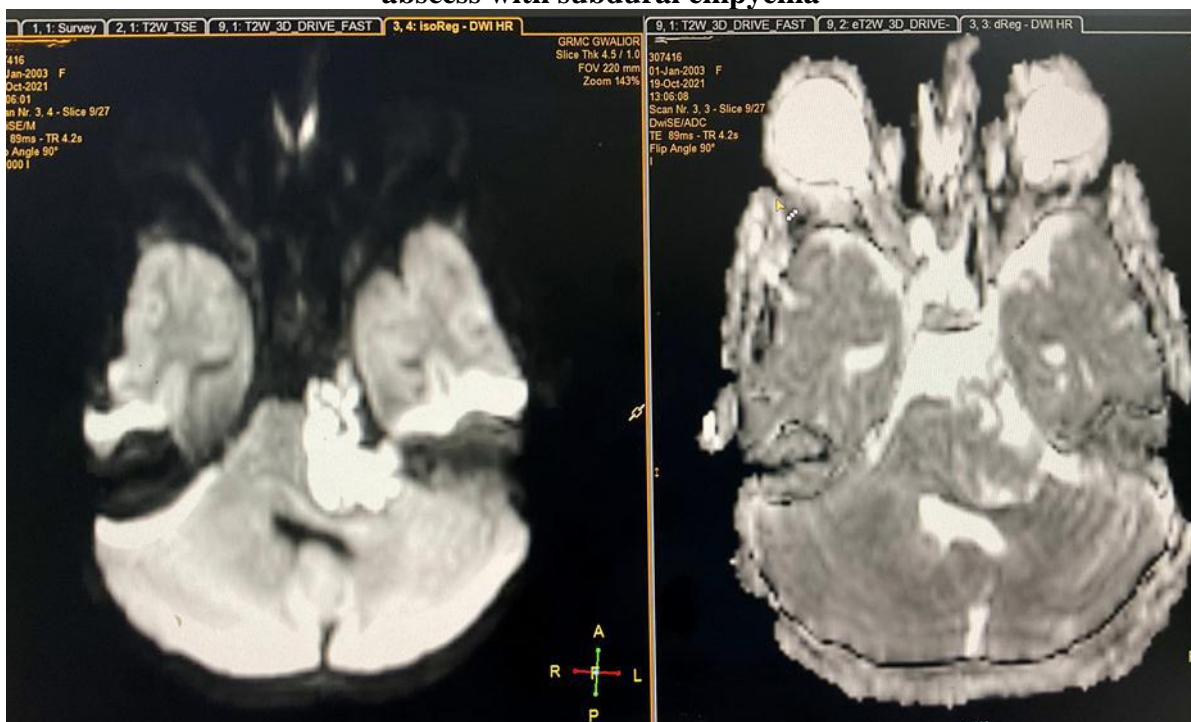

Figure 2: A well delineated lobulated extraaxial lesion noted in left cerebropontine angle insinuating along left basal cistern, showing very bright signal intensity on DWI with intermediate ADC value suggestive of Epidermoid cyst
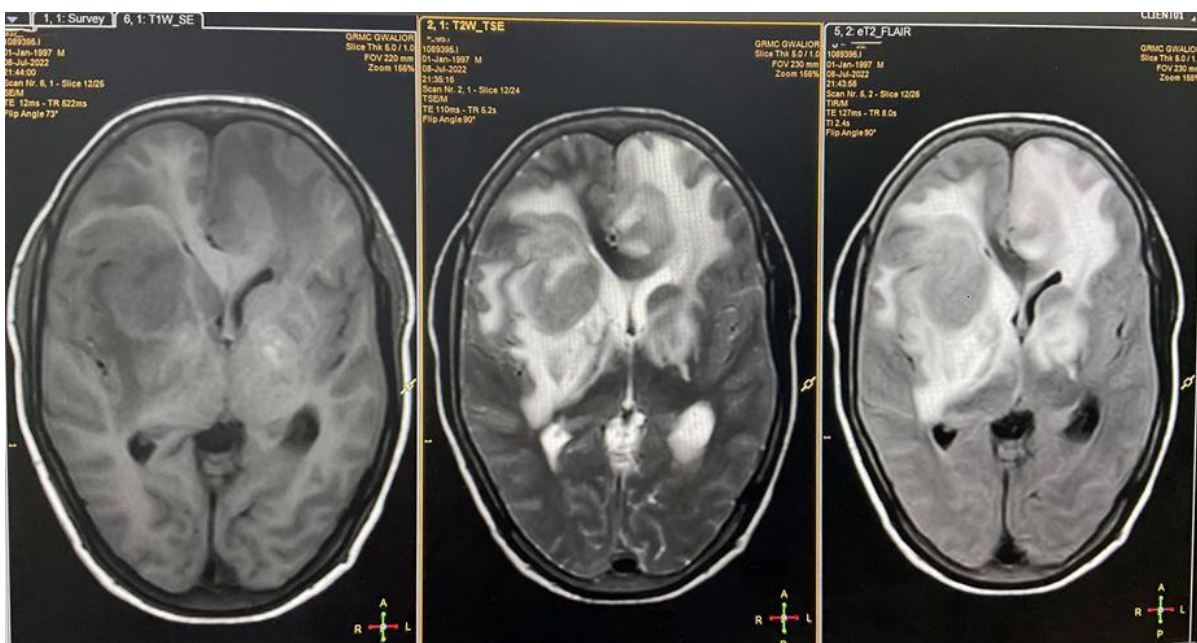
Figure 3: Patient is a known case of HIV, MRI brain with contrast study shows, Few well defined intraaxial lesions showing DWI restriction and low signal intensity on ADC with surrounding FLAIR hyper intensity noted in bilateral frontal lobes suggestive of Lymphoma

Figure 4: Diffuse T2 FLAIR hyperintesity showing multiple areas of DWI restriction notes in pons suggestive of Central pontine myelinosis
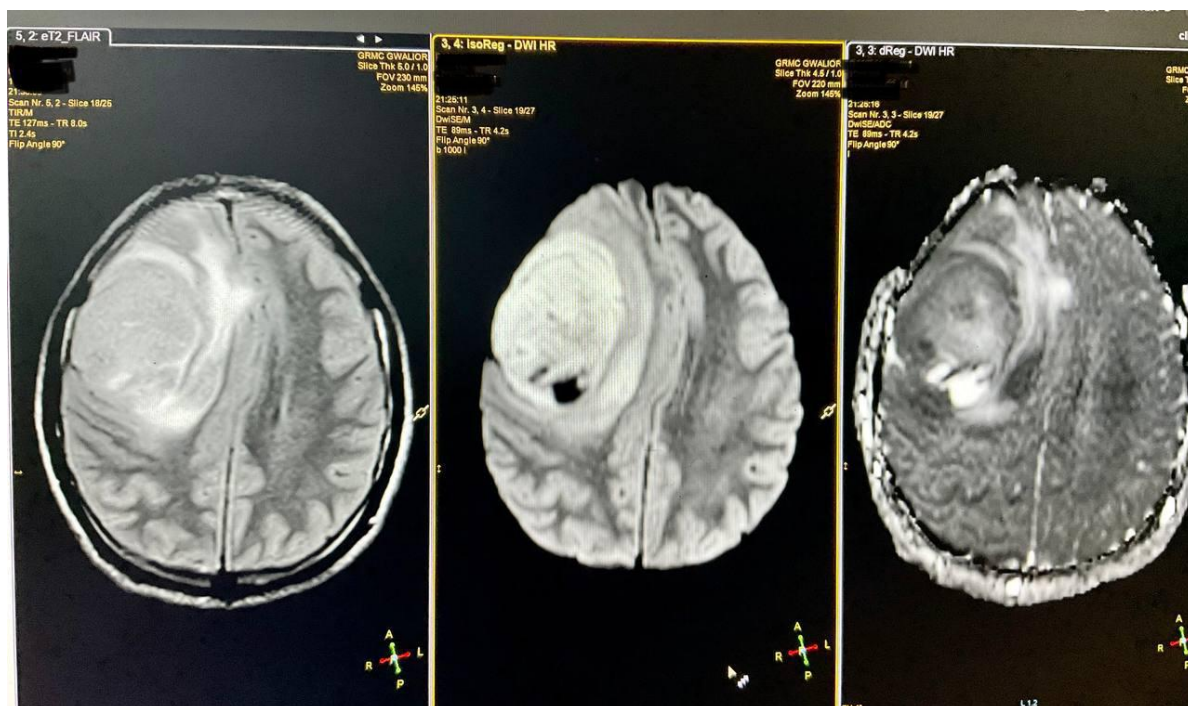
Figure 5: A T2 heterogenously hyperintense lesion noted in right frontal region with significant perilesional edema, showing DWI restriction and low ADC signals suggestive of High grade glioma

REFERENCES

1. Prasanth SR, Shaji CV, Kabeer KA, Mohan R, Parvathy G. Platform Session 01,Epilepsy 08: 30-09: 30 h, Friday, November 11, 2016 Hall A EO1/4.
2. Darweesh AM, Badawy ME, Hamesa M. Magnetic resonance spectroscopy and diffusion imaging in the evaluation of neoplastic brain lesions. Egypt J Radiol Nuclear Med 2014; 45:485–493.
3. Yu X, Liu Z, Tian Z, Li S, Huang H, Xiu B, et al. Stereotactic biopsy for intracranial space-occupying lesions: clinical analysis of 550 cases. Stereotact Funct Neurosurg 2000; 75:103–108.
4. Alesch F, Pappaterra J, Trattnig S, et al. The role of sterotactic biopsy in radiosurgery. Acta Neurochir Suppl (Wein) 1996; 63:20–24.
5. El-Sirafy MN, Ali IR, Hegab SE, et al. Clinical feasibility of diffusionweighted magnetic resonance imaging using 0.2 Tesla machines in differentiating brain infections from brain tumors: an Egyptian study. Egypt J Neurol Psychiat Neurosurg 2011; 46:299–310.
6. Klug N, Ellams ID. Difficulties in the differential diagnosis of brain abscesses. In: Schiefer W, Klinger M, Brock M, editors. Advances in neurosurgery 9. Berlin, Germany: Springer-Verlag; 1981. 61–66.
7. Abou Sheisha DM, Amin MA, Soliman AY. Role of diffusion weighted imaging and proton magnetic resonance spectroscopy in ring enhancing brain lesions. Egypt J Radiol Nuclear Med 2014; 45:825–832.
8. Cartes-Zumelzu FW, Stavrou I, Castillo M, Eisenhuber E, Knosp E,Thurnher MM. Diffusion-weighted imaging in the assessment of brain abscesses therapy. Am J Neuroradiol 2004; 25:1310-1317.

9.   Lai PH, Weng HH, Chen CY, Hsu SS, Ding S, Ko CW, et al. In vivo differentiation of aerobic brain abscesses and necrotic glioblastomas multiforme using proton MR spectroscopic imaging. Am J Neuroradiol 2008; 29:1511–1518.

10. Schaefer PW, Grant PE, Gonzalez RG. Diffusion-weighted MR imaging of the brain. Radiology 2000; 217:331–345.

11. Chenevert TL, Brunberg JA, Pipe JG. Anisotropic diffusion in human white matter: demonstration with MR techniques in vivo. Radiology 1990;177:401–405.

12. Stadnik TW, Demaerel P, Luypaert RR, Chaskis C, Van Rompaey KL,Michotte A, Osteaux MJ. Imaging tutorial: differential diagnosis of bright lesions on diffusion-weighted MR images. Radiographics 2003; 23:e7.

13. Rowley HA, Grant PE, Roberts TP. Diffusion MR imaging. Theory and applications. Neuroimaging Clin N Am 1999; 9:343–361.

14. Bulakbasi N, Kocaoglu M, Ors F, Tayfun C, Uçöz T. Combination of single-voxel proton MR spectroscopy and apparent diffusion coefficient calculation in the evaluation of common brain tumors. Am J Neuroradiol 2003; 24:225–233.

15. Guo AC, Cummings TJ, Dash RC, Provenzale JM. Lymphomas and high-grade astrocytomas: comparison of water diffusibility and histologic characteristics. Radiology 2002; 224:177–183.

16. Rumboldt Z, Camacho DL, Lake D, Welsh CT, Castillo M. Apparent diffusion coefficients for differentiation of cerebellar tumors in children. Am J Neuroradiol 2006; 27:1362–1369.

17. Bernardini GL. Diagnosis and management of brain abscess and subdural empyema. Curr Neurol Neurosci Rep 2004; 4:448–456.

18. Chen S, Ikawa F, Kurisu K, Arita K, Takaba J, Kanou Y Quantitative MR. evaluation of intracranial epidermoid tumors by fast fluid-attenuated inversion recovery imaging and echo-planar diffusion-weighted imaging. Am J Neuroradiol 2001; 22:1089–1096.

19. Kang BK, Na DG, Ryoo JW, et al. Diffusion-weighted MR imaging of intracerebral hemorrhage. Korean J Radiol 2009; 2:183–191.

20. Rima K, Rohit G, Anjali P, Veena C. Role of diffusion weighted MR imaging in early diagnosis of cerebral infarction. Ind J Radiol Image. 2003; 3(2):213-7.

21. Drevelegas A, Papanikolaou N. Imaging modalities in brain tumors. In Imaging of brain tumors with histological correlations 2011 (pp. 13-33). Springer, Berlin, Heidelberg.

22. Schaefer PW, Grant PE, Gonzalez RG. Diffusion-weighted MR imaging of the brain. Radiology. 2000 Nov; 217(2):331-45.

23. Gupta S, Suresh A, Reddy KV, Shrivastava S, Tripathy S. Diffusion Weighted Versus Conventional MRI in Diagnosis and Characterization of Intracranial Space Occupying Lesions.

24. Santos, G., Leite, C., Machado, L., McKinney, A. and Lucato, L. (2012). Reduced Diffusion in Neurocysticercosis: Circumstances of Appearance and Possible Natural History Implications. American Journal of Neuroradiology, 34(2), .310-316.

25. Sener R. Herpes simplex encephalitis: diffusion MR imaging findings. Computerized Medical Imaging and Graphics. 2001;25(5):391-397.

26. Rollin N, Guyotat J, Streichenberger N, Honnorat J, Tran Minh VA, Cotton F. Clinical relevance of diffusion and perfusion magnetic resonance imaging in assessing intraaxial brain tumors. Neuroradiology. 2006 Mar;48(3):150-9.

27. Desprechins B, Stadnik T, Koerts G, Shabana W, Breucq C, Osteaux M. Use of diffusion-weighted MR Imaging in differential diagnosis between intracerebral necrotic tumors and cerebral abscesses. AJNR Am J Neuroradiol 1999;20: 1252–7.

28. Chiang IC, Hsieh TJ, Chiu ML, Liu GC, Kuo YT, Lin WC. Distinction between pyogenic brain abscess and necrotic brain tumor using 3-tesla MR spectroscopy, diffusion and perfusion imaging. The british journal of Radiology. 2009 Oct;82(982):813-20.

29. Chang S, Lai P, Chen W, Weng H, Ho J, Wang J et al. Diffusion-weighted MRI features of brain abscess and cystic or necrotic brain tumors. Clinical Imaging.2002; 26(4):227-236.

30. da Cruz LC, Kimura M. Neuroimaging and genetic influence in treating brain neoplasms. Neuroimaging Clinics. 2015 Feb 1;25(1):121-40.

31. Svolos P, Kousi E, Kapsalaki E, Theodorou K, Fezoulidis I, Kappas C, Tsougos I. The role of diffusion and perfusion weighted imaging in the differential diagnosis of cerebral tumors: a review and future perspectives. Cancer Imaging. 2014 Dec;14(1):1-20.

32. Bergui, M., Zhong, J., Bradac, G. and Sales, S. Diffusion-weighted images of intracranial cyst-like lesions. Neuroradiology, 2001: 43(10), 824-829.

33. Kohla GA, AbdelAziz EM, Abd-Elwahab HM. The role of diffusion-weighted MRI in characterization of intracranial cystic lesions. The Scientific Journal of Al-Azhar Medical Faculty, Girls. 2022 Jan 1;6(1):51.

34. Schaefer PW, Grant PE, Gonzalez RG. Diffusion-weighted MR imaging of the brain. Radiology. 2000 Nov;217(2):331-45.

35. Ruzek KA, Campeau N and Miller GM American Journal of Neuroradiology February 2004, 25 (2) 210-213.

36. Rueda-Lopes FC, Hygino da Cruz Jr LC, Doring TM, Gasparetto EL. Diffusion-weighted imaging and demyelinating diseases: new aspects of an old advanced sequence. American Journal of Roentgenology. 2014 Jan;202(1):W34-42.