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Role of Diffusion Weighted Magnetic Resonance Imaging in Intracranial Lesions

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ABSTRACT

Background

Diffusion weighted imaging (DWI) is used in a wide range of medical diagnosis purpose to evaluate the intracranial pathological conditions. Particularly, this method provides a specificity to obtain the information on conventional sequence analysis.

Materials and Methods

The present study was conducted in the Department of radiodiagnosis, Sri Lakshmi Narayana institute of medical sciences, Puducherry. The study was conducted by the Ethical committee permission and informed consent received from the participants. The conventional MRI and diffusion weighted images of patients (n=50) were analysed and the statistical evaluation was carried out by the software.

Results

Majority of Patients were in age group 61-70years (22%) and mean age was 43 years. No sex preponderance was observed and majority of lesions were in intra-axial (66%) at Frontal Lobe than extra-axial. Many patients showed intracranial neoplastic lesions (38%) and common with metastasis (12%) and Meningioma (10%). Arachnoid cysts were predominate type of non-neoplastic cystic lesions (10%). We observed that diffusion weighted imaging revealed significantly different ADC values among different intracranial lesions. High grade gliomas having diffusion restriction with reduced ADC values in comparison to Low grade gliomas.

Conclusion

The present study showed that dwi and adc is useful to diagnose intracranial lesions better than the conventional MR imaging.

Keywords:

ADC (Apparent diffusion coefficient), DWI, Intracranial lesions, MRI (Magnetic resonance imaging), T1W (T1 weighted), T2W (T2 weighted)

1.Introduction

Intracranial space occupying lesion is a term that generally used to identify any lesion, whether vascular or neoplastic or inflammatory in origin which increases the volume of intracranial contents and leads to a rise in the intracranial pressure. Neoplasms may be benign or malignant and primary or metastatic. Non-neoplastic lesions include hematomas, cerebral abscesses including Toxoplasmosis, cysts including arachnoid cysts, colloid cysts, dermoid cysts, epidermoid cysts, vascular malformations and inflammatory or parasitic masses such as cerebral amoebiasis and cystecercosis within cranial cavity.(1) Thus, Intracranial lesions are diverse group of lesions that pose immediate threat to patient’s lives, no matter their local or metastatic origin,

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benign or malignant nature. These lesions have severe clinical courses and need to be diagnosed as early as possible for best treatment.

CNS neoplasms constitute 1.9% of all malignant tumors in India (2). The annual incidence of CNS tumors ranges according to published Western data from 10 to 17/100,000 persons for intracranial tumors, in which half of them are primary tumors and the rest are metastatic. 20% of the CNS tumors account for all cancers of childhood. In children younger than 15, brain tumors are second only to acute lymphoblastic leukemia as the most common form of cancer.(3) This gives rise to urgent need for accurate characterization and localization of space-occupying lesions by cytology and histology, many a times requiring special diagnostic techniques.
The diagnosis of intracranial lesion can be made radiologically or through cytological and histopathological means. The later having a disadvantage of being invasive. CT scan and conventional MRI are able to provide a provisional diagnosis as well as localisation of CNS lesion, the lumbar puncture and biopsy just provide information about the nature of lesion but do not localise the lesion. Skull X-ray tells about the calcified intracranial lesions and their location but is not accurate and specific. CT scan and conventional MRI are able to provide a provisional diagnosis as well as localisation of CNS lesion; however, their accuracy is less than ideal.

Diffusion weighted imaging (DWI) is a specialized magnetic resonance imaging technique that has a wide range of applications in the evaluation of intracranial pathological conditions. It provides a specific diagnosis in few conditions like stroke, and adds to the information provided by conventional sequences in many other intracranial lesions (4). Diffusion-weighted magnetic resonance (DW MR) imaging provides unique information on the viability of brain tissue. It provides image contrast that is dependent on the molecular motion of water molecules within and between the intracellular and extracellular spaces and it provides unique biological and clinically relevant information about the tissue composition and architectural organization that is substantially altered by disease process (5).

Diffusion magnetic resonance imaging (MR) uses the Brownian motion of molecules to derive images. In patients of acute stroke, DWI demonstrates reduction in diffusion in a vascular territory which is affected by ischemia. Similarly, decreased diffusion is present in the center of pyogenic abscesses and aids in the MR diagnosis of a ring-enhancing cerebral mass (6-7). In addition, tumors such as lymphoma and PNET also demonstrate decreasing diffusion, adding valuable information to the radiologist when formulating a differential diagnosis of a cerebral mass lesion (8).

They also help in differentiating tumors such as glioblastoma, primary cerebral lymphoma, and metastasis. Diffusion imaging can also aid in the evaluation of Diffuse Axonal Injury (DAI) in patients with closed head injury when imaged within 48 hours of injury. The role of DWI in differentiating cerebral abscess from necrotic tumors and arachnoid cysts from epidermoid tumors is well established. (9).

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DWI also plays an important role in the diagnosis of multiple sclerosis, Creutzfeldt-Jakob disease (CJD), herpes encephalitis and other types of intracranial infections.(10) Further, the imaging features of these lesions with ADC and T1 weighted, T2 weighted, FLAIR Imaging help todifferentiate various intracranial lesions. The technique most commonly used to acquire the DWI is an ultrafast one, echo-planar imaging (EPI); this technique decreases the scanning time significantly ranging from few seconds to 2 minutes and eliminates movement artifacts. Thus the present study aimed to evaluate DWI characteristics of various intra cranial lesions so as to formulate short meaningful differential diagnosis and guide the treatment.

2. Materials and Methods

This observational study Role of Diffusion Weighted Imaging in Intracranial lesions was done in the Department of Radio diagnosis Sri Lakshmi Narayan Institute of Medical Sciences , Puducherry,India. The conventional MRI and diffusion weighted images of a total of 50 patients who were diagnosed as having Intra cranial lesions, were evaluated. All patients had undergone Magnetic Resonance Imaging on a MRI scanner. The final MRI diagnosis was made on basis of morphology of lesion on conventional sequences T1, T2, and then correlated with findings on DWI/ADC. The data was recorded on prestructured proforma for study and analysed. Descriptive statistics was carried out to identify the characteristics and features of the collected data Mean and percentage was used to represent data Chi square test was applied to identify the association between variables. Microsoft excel was used to prepare the master charts.

3. Results

Patients were distributed into 8 groups on basis of age (Table 1,Figure. 1). Majority of Patients in our study were in age group 61-70 years (20%), followed by 21-30 years (18%). Mean age of patient was 43 years. The second group was categorized based on the gender (Table 2, Figure. 2). No sex preponderance was observed in our study with 54% patients being male and 46% being females. All patients were subjected to MRI Brain and on basis of location classified into two groups. (Table 3, Figure 3). Majority of lesions in our study were intra-axial(66%), whereas only 34% cases were extra-axial. Classification of Intra Cranial lesions on basis of their location in Brain parenchyma(Table 4, Figure 4). . Frontal Lobe was the most common site of involvement among intra-axial lesions(22%). The involvement of C.P. angle was (10%) in extraaxial lesions. Distribution of patients on the basis of diagnosis on conventional MRI sequence(T1,T2,).(Table 5, Figure. 5). Majority of patients in our study were of Stroke (16 %) followed by Arachnoid cysts (12%), Metastasis (12%) and Meningiomas (10%). All cases were subjected to DW imaging and ADC values of the lesions were calculated.. (Table 6 and Figure. 6).

Table 1. Distribution of Patients on basis of Age

S. No.	AGE	NUMBER	PERCENTAGE
1	0-10	3	6

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 1468 - 1497
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2	11--20	5	10
3	21-30	9	18
4	31-40	5	10
5	41-50	7	14
6	51-60	7	14
7	61-70	10	20
8	>70	4	8
		50	100

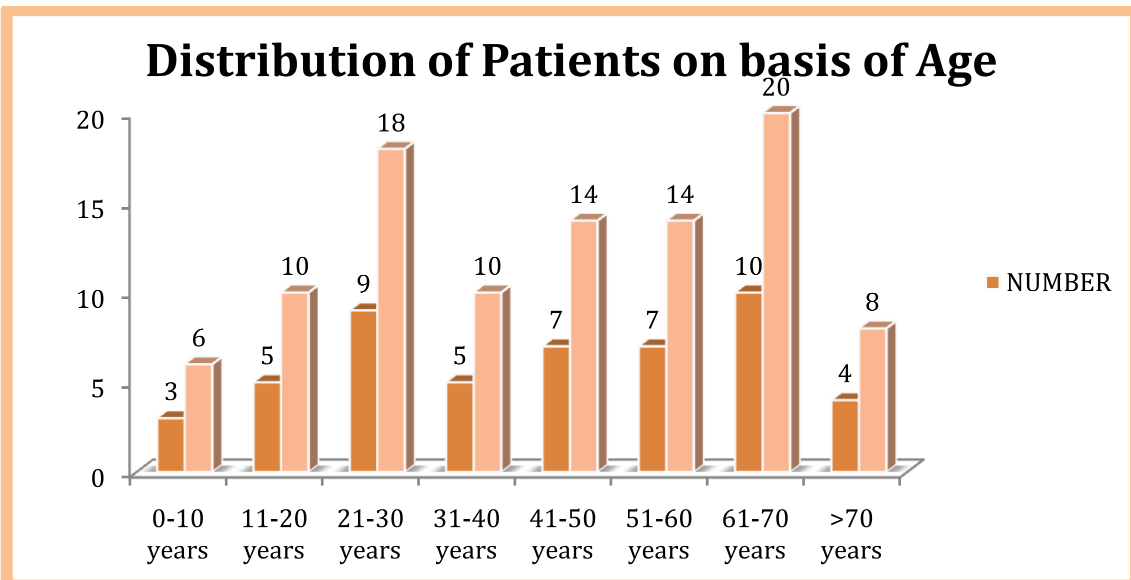

Figure. 1. Distribution of Patients on basis of Age

Table 2. Distribution of patients according togender

S No.	GENDER	NUMBER	PERCENTAGE
1	MALE	27	54%
2	FEMALE	23	46%

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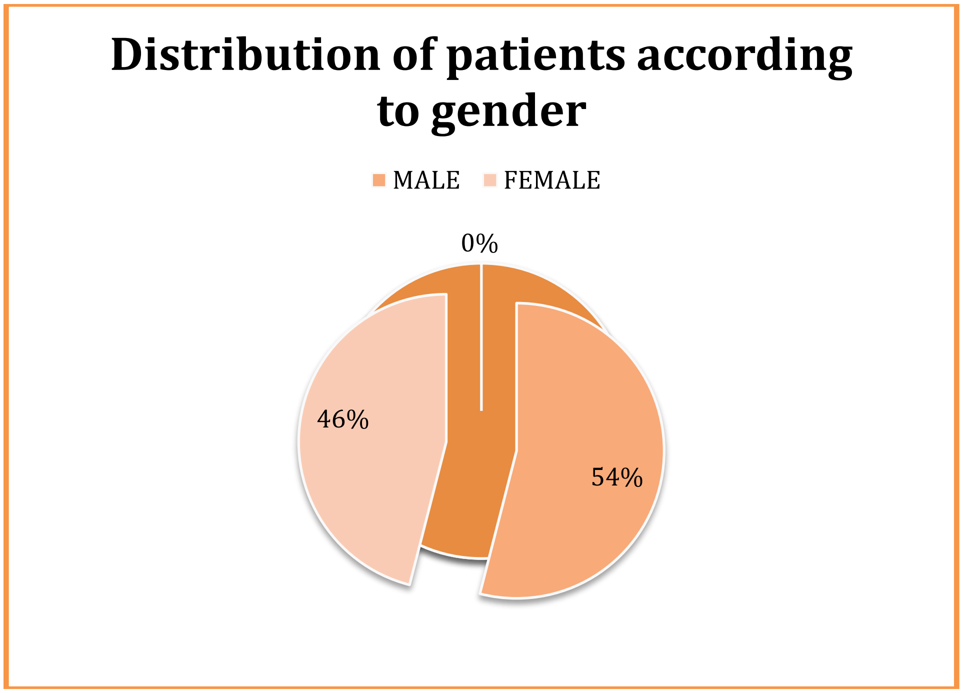

Figure. 2. Distribution of patients according togender

Table 3. Distribution of patients according to location of lesion

S. No.	Location	Number	Percentage
1	Intra axial	33	66%
2	Extra axial	17	34%
	Total	50	100

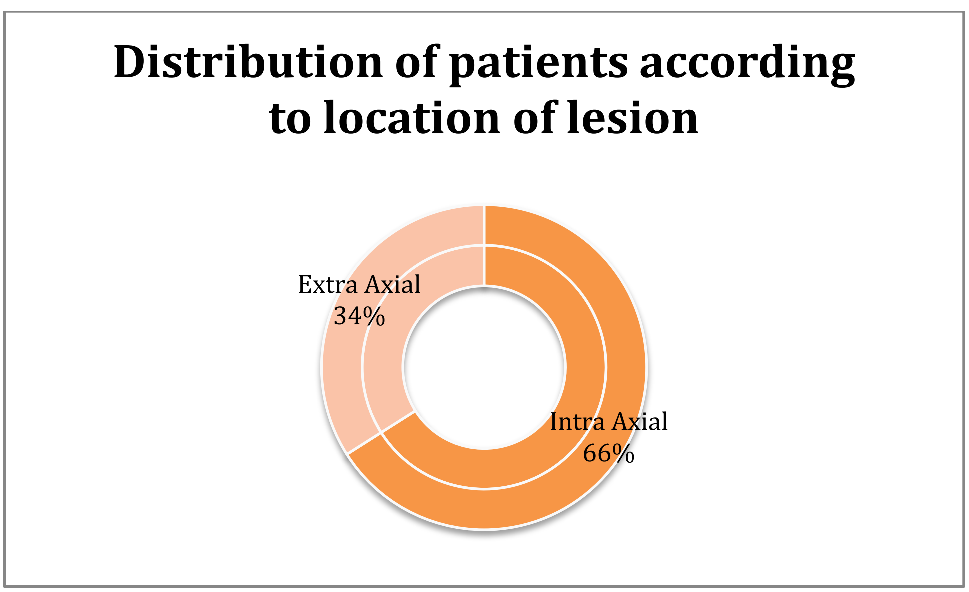

Figure. 3. Distribution of patients according to location of lesion

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Table 4. Distribution of Intra Cranial Lesions

INTRA- AXIAL	NUMBER	PERCENTAGE
FRONTAL LOBE	11	22%
TEMPORAL	5	10%
PARIETAL	1	2%
OCCIPITAL LOBE	1	2%
PARIETO-TEMPORAL	2	4%
FRONTO-PARIETAL	2	4%
FRONTO-PARIETO-OCCIPITAL	1	2%
FRONTO-PARIETO-TEMPORO-OCCIPITAL	2	4%
CEREBELLUM	2	4%
LENTIFORM NUCLEUS	1	2%
PONS	2	4%
PERI-CALLOSAL AREA	1	2%
GANGLIOCAPSULAR	2	4%
TOTAL	33	66%
EXTRA AXIAL		
FALX	1	2%
CP ANGLE	5	10%
LOBAR CONVEXITY	7	14%
CLINOID PROCESS	1	2%
SULCAL SPACES	3	6%
	17	34%

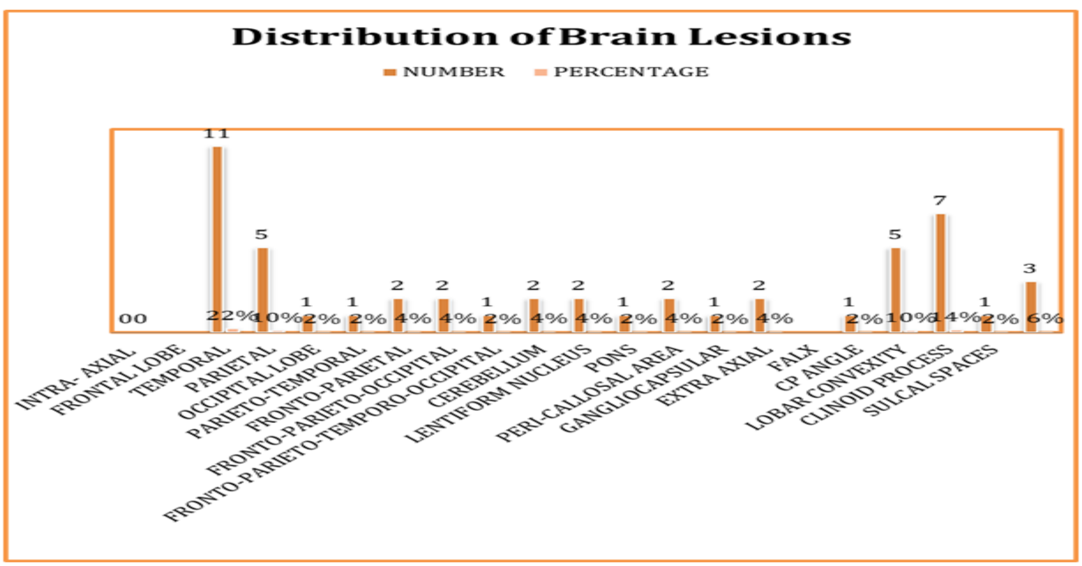

Figure 4. Distribution of Intra Cranial Lesions

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Table 5. Patients were distributed on basis of diagnosis on conventional MRI sequencesmorphology.

S No	Provisional diagnosis on conventional MR sequences	NUMBER OF PATIENTS	PERCENTAGE
1	High grade glioma	1	2%
2	Low grade glioma	2	4%
3	Meningioma	5	10%
4	Metastasis	6	12%
5	Cavernoma	1	2%
6	Schwannoma	3	6%
7	Lipoma	1	2%
8	Abscess	3	6%
9	Tuberculoma	4	8%
10	Meningitis	2	4%
11	Encephalitis	4	8%
12	NCC	3	6%
13	Stroke	8	16%
14	Arachnoid cyst /	6	12%
	Epidermoid cyst		
15	Central pontine	1	2%
	myelinolysis		
	TOTAL	50	100

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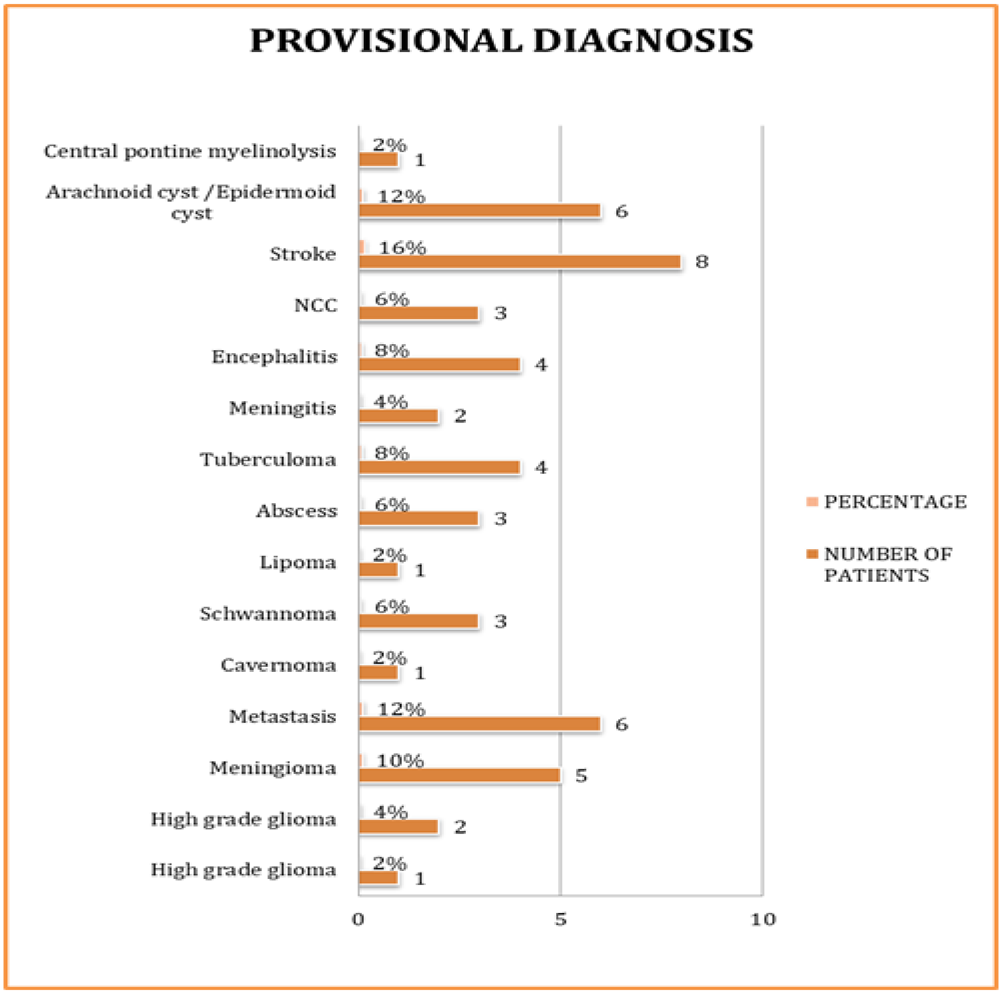

Figure 5. Patients were distributed on basis of diagnosis on conventional MRI sequencesmorphology.

Table 6. Characterisation of Intracranial lesion on DWI/ ADC values.

S. No	Provisional diagnosis on conventional MR sequences	CONVENTIONAL MRI FEATURES	DWI/ADC FEATURES
1	High grade glioma	Predominantly hyperintense, Mixedintensity lesion	Restriction/ low ADC Signal
2	Low grade glioma	Iso to Hyperintense	No Restriction/ high ADC Signal
3	Meningioma	Mixed intensity predominantly Hyperintense	No Restriction/ high ADC Signal
4	Metastasis	Mixed intensity predominantly Hyperintense	No Restriction/ High ADC Signal
5	Cavernoma	Mixed intensity Predominantly Hypointense	No Restriction/ High ADC Signal
6	Schwannoma	Mixed intensity predominantly Hyperintense	No Restriction/ High ADC Signal

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7	Lipoma	Hyperintense	No Restriction/ Low ADC Signal
8	Meningitis	Hypointense	No Restriction/ High ADC Signal
9	Abscess	Hyperintense	Restriction/ low ADC Signal
10	Tuberculoma	Hypo to hyperintense	Restriction/ Low ADC Signal
11	Encephalitis	Hypo to hyperintense	Restriction/ Low ADC Signal
12	NCC	Hypointense core with with presence of eccentric scolex , hyperintense core with hypointense scolex	No Restriction/ High ADC Signal
13	Epidermoid cyst/arachnoid cyst	Hypointense to adjacent brain parenchyma , Hyperintense to adjacent brain parenchyma	No Restriction/ High ADC Signal (Arachnoid) Restriction/Low ADC Signal (Epidermoid)
14	Stroke	Predominantly hyperintense, Mixed intensity lesion	No Restriction/ High ADC Signal(Chronic) Restriction/ Low ADC Signal(Acute/ haemorrhagic)
15	Central pontine myelinolysis	Hyperintense	Restriction/ Low ADC Signal

The diffusion weighted imaging revealed significantly different ADC values among different intracranial lesions (Table.6). High grade gliomas having reduced ADC values in comparision to Low grade gliomas. Degenerating neurocysticercus granulomas having higher ADC values in comparision to tuberculomas. Epidermoid having significantly lower ADC values in comparison to Arachnoid cysts. One case having morphological appearance of arachnoid cyst was classified as epidermoid cyst on the basis of ADC values. In Stroke Acute stroke has lower ADCvalues as compared to Chronic Stroke. Meningiomas having lower ADC values than Schwanomas. Metastases showed varied ADC values depending on their nature. Pyogenic abscesses revealed lower ADC values in comparison to encephalitis except for one early presenter (<2days). On basis of Final MR diagnosis with DWI and ADC values, patients were distributed as follows(Table7 and Figure. 6)

Table 7. Distribution of patients on the basis of final MR diagnosis.

S no	ETIOLOGY	Provisional diagnosis with DWI	Number of patients	Percentage
1	TUMOURS	High grade glioma	1	2%
		Low grade glioma	2	4%
		Meningioma	5	10%
		Metastasis	6	12%
		Cavernoma	1	2%

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		Schwannoma	3	6%
		Lipoma	1	2%
2	INFECTIONS	Abscess	3	6%
		Tuberculoma	4	8%
		Meningitis	2	4%
		Encephalitis	4	8%
		NCC	3	6%
3	CYSTIC LESIONS	Arachnoid cyst	5	10%
		Epidermoid cyst	1	2%
4	DEMYLEINATING LESION	Central pontine myelonosis	1	2%
5	STROKE	Acute infarct	2	4%
		Chronic Stroke	2	4%
		Haemorrhagic Stroke	2	4%
	TOTAL		50	100

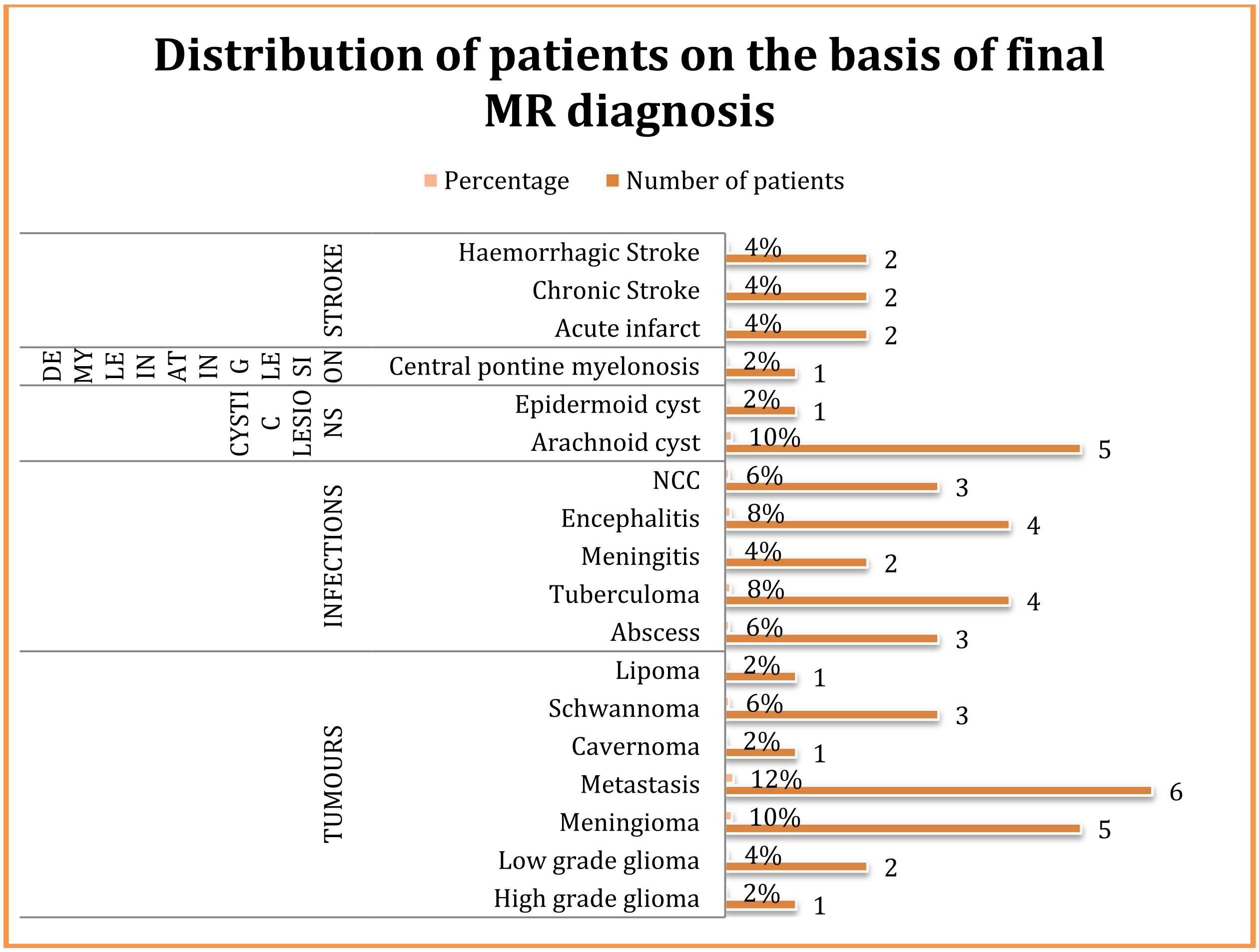

Figure 6. Distribution of patients on the basis of final MR diagnosis.

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Majority of patients in our study were Intracranial neoplastic lesions accounted for 38 % of the cases, of which Metastasis(12%) andMeningiomas(10%) were most common followed by Infective pathology (32%), of which Tuberculomas (8%) and Encephalitis (8%) were the most common lesions. Arachnoid cysts were the most common non-neoplastic cystic lesions(10%)

The present study also analysed the MRI scan details of the patients. Plate. 1 showed that the MRI findings in case of tuberculoma involving the left lateral cerebellar hemisphere appearing hypointense on both T1WI and FLAIR, with surrounding perilesional edema. The lesion appeared predominantly hypointense on DWI with mean ADC value of 1197 x 10-6 mm^2/s on ADC map.

MRI findings in a case of low grade glioma in left medial / inferior frontal cortical / subcortical white matter. It appears hypointense on T1 ,hyperintense on T2 and DWI. The mean ADC value of the lesion was found to be 1899 x $10^{-6}mm^2$/s (Plate 2).

The MRI findings in a case of metastasis showed T1 hypointense and heterogeneously hyperintense lesion on T2 and DWI. The mean ADC value was calculated from the solid portion of the lesion and it was found to be 921x 10^{-6} mm2/s (Plate. 3). MRI in a case of Acoustic Schwannoma as a well defined extra-axial SOL in right CP angle region appears predominantly hypointense on T1 and heterogeneously isointense on T2/DWI having multifocal intralesional tiny hyperintense signals. The mean ADC value was found to be 1005x 10-6 mm^2/s (Plate.4). Figure 7.MRI in a case of High Grade Glioma reveals an heterogenous T2 hyperintense lesion with perilesional edema involving the left cerebellar hemisphere. DWI reveals diffusion restriction in in the wall of the lesion and no restriction in the center of the lesion which appears iso to mildly hypointense on ADC.

MRI findings of Arachnoid cyst revealed cystic lesion in the retro cerebellar region in the midline .It appears hypointense on T1, hyperintense on T2 and suppressed on FLAIR. No evidence of restriction seen on DWI/ADC mapping with an estimated ADC value of 2766 x 10^{-6} mm^2/s (High, Plate. 6).

This is a case of neurocysticercosis showing small rounded predominantly cystic lesion, with eccentric nodular component , in the left frontal subcortical white matter with mild perilesional edema, which appears hypointense on T1WI, iso to hyperintense on T2WI. The mean ADC value is 1409 x 10^{-6} mm^2/s (Plate. 7).

MRI findings of Epidermoid Cyst revealed an extra axial T1 hypo/ T2 and DWI hyperintense cystic mass lesion at right CP angle and prepontine cistern region. The ADC value was 731 x 10-6 mm^2/s. The ADC values are significantly low in comparison to similar appearing Arachnoid cyst (Plate. 8). MRI findings of Cerebral abscess in the right lateral frontal region appears hypointense on T1, iso to hyperintense on T2, , restricted diffusion on DWI/ADC images with moderate perilesional edema. The mean ADC value was 685 x 10^{-6} mm2/s Plate. 9). MRI findings in a case of right lateral cerebellar convexity Meningioma, appearing homogeneously isointense on T1 and T2,. The mean ADC value is 781 x 10^{-6} mm2/s (Plate. 10). A case of Lipoma in anterior interhemispheric region extended cingulate sulcus on either side of the midline. It appears hyperintense on T1/T2 and hypointense on DWI/ADC. The mean ADC value was 173 x 10^{-6} mm^2 (Plate. 11).

MRI findings in a case of Cavernoma revealed the presence of white matter in left inferior frontal gyrus subcortical. Core of the lesion appears isointense on T1, heterogeneously iso-to-hyperintense on T2 images and markedly hypointense on DWI. The mean ADC value was 896 x 10^{-6} mm2/s (Plate. 12). A case of acute stroke in right high frontal and parietal region showed with focal area of T2W/FLAIR hyper intensity and further it showed that the diffusion restriction with ADC inversion (Plate.13).

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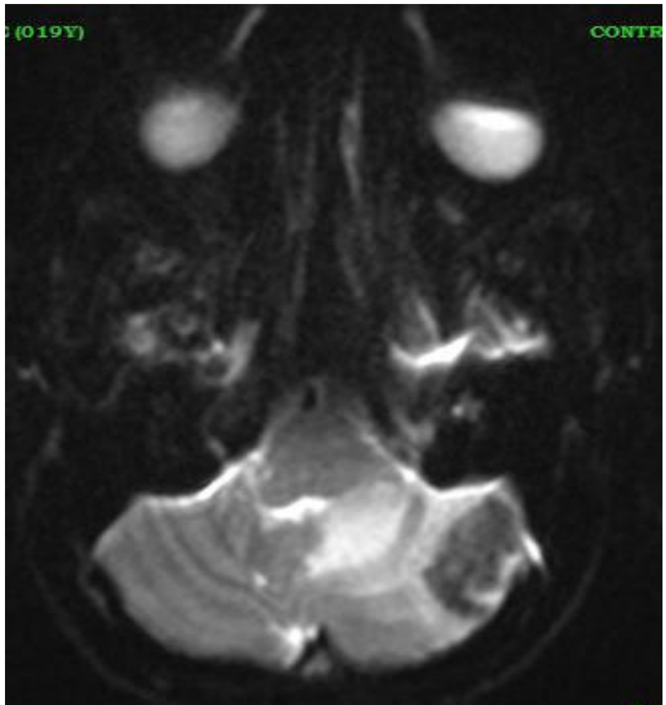

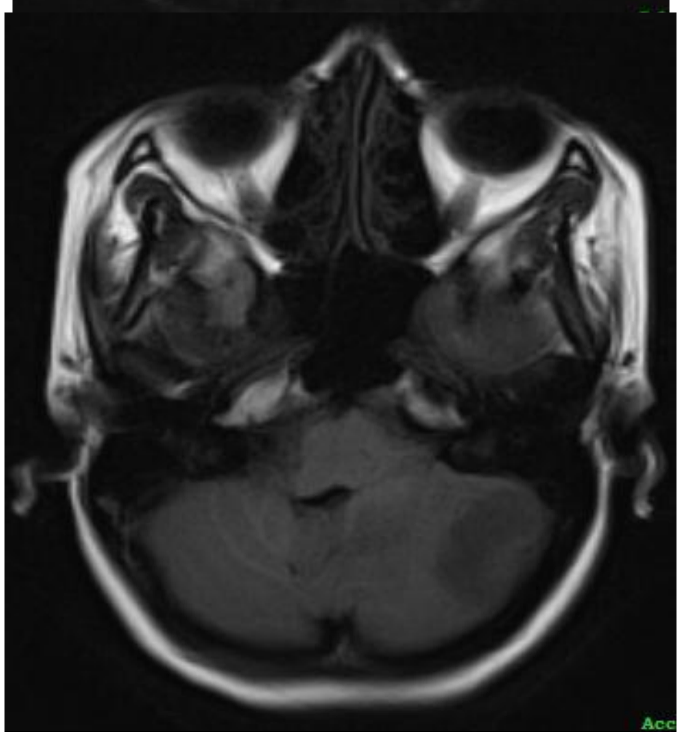

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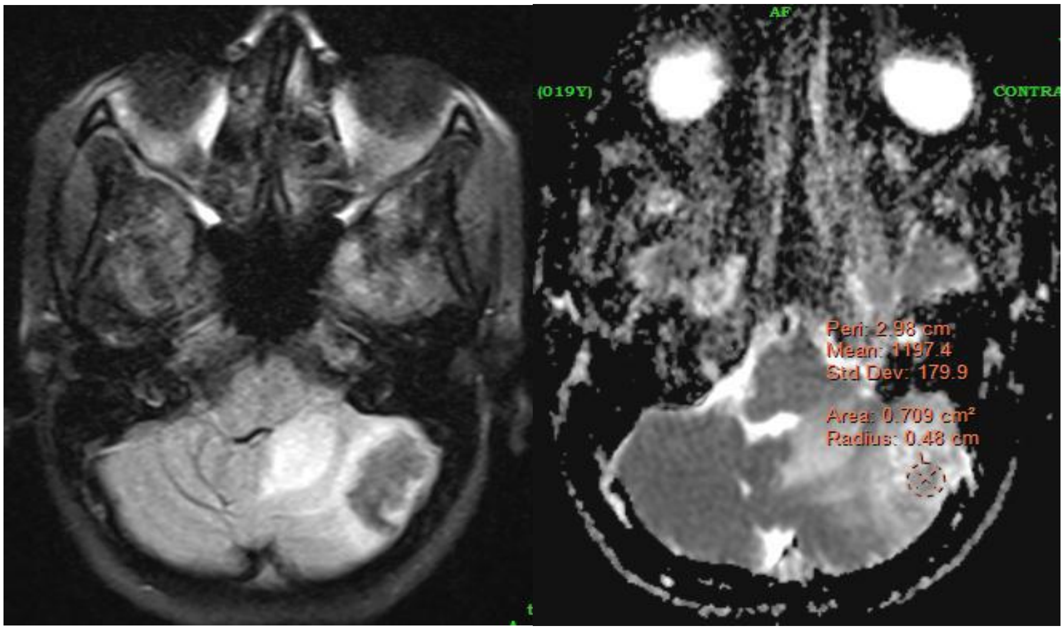
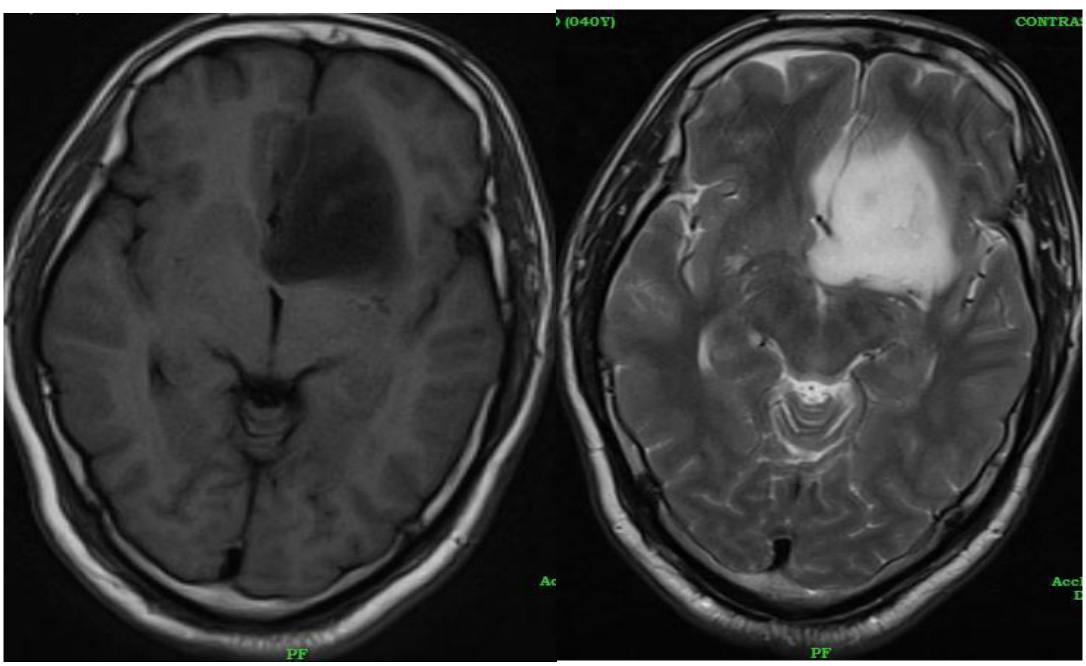


Plate 1.



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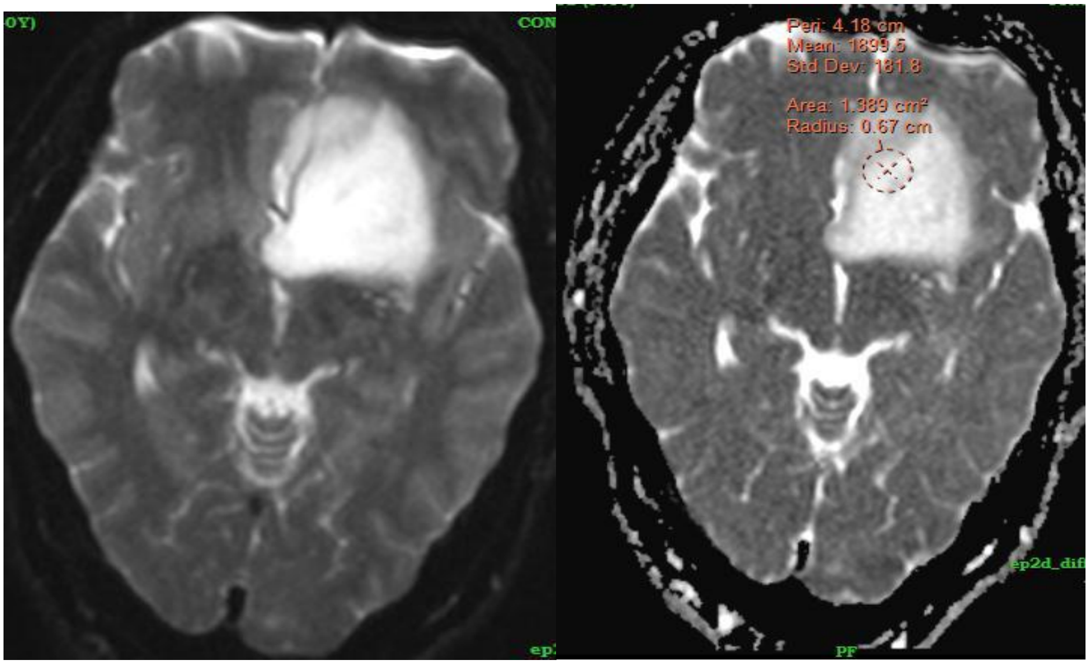
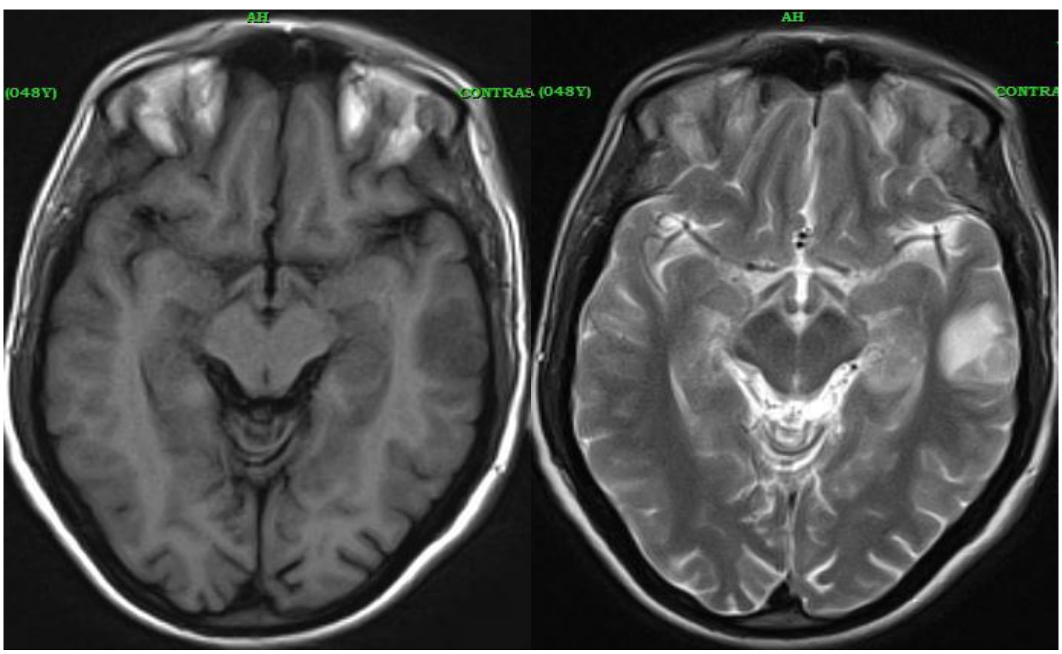


Plate. 2.



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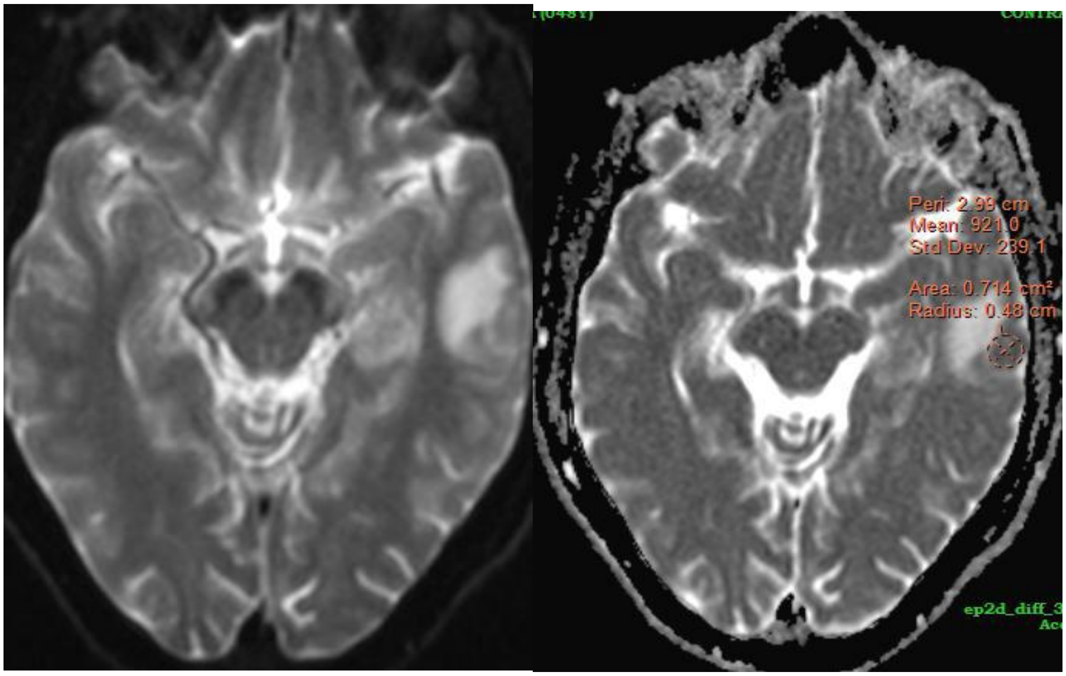
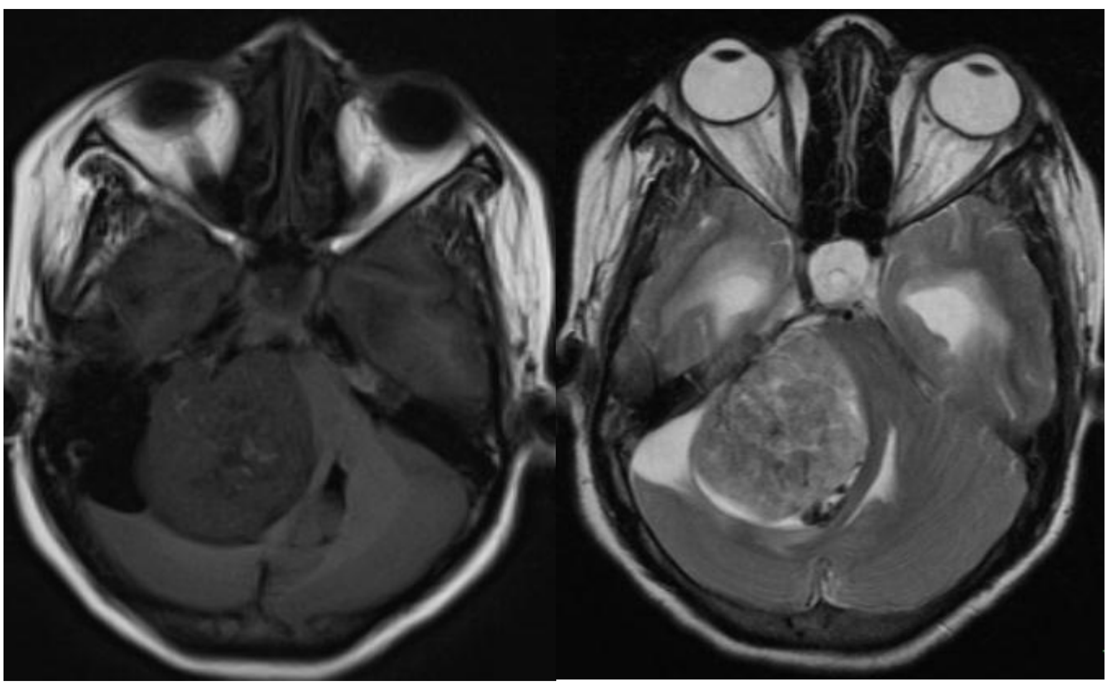


Plate. 3.



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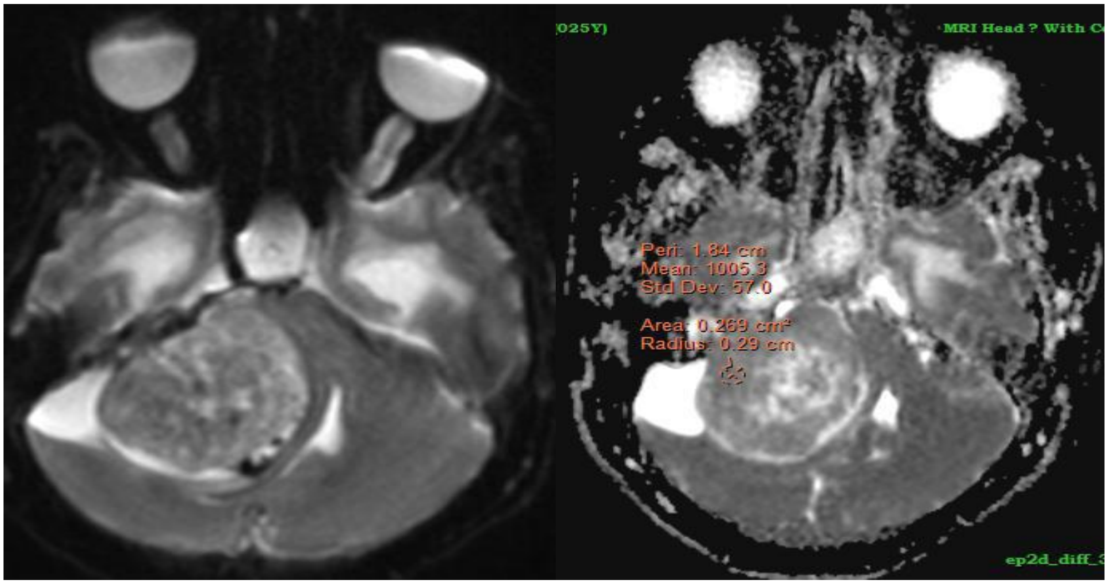
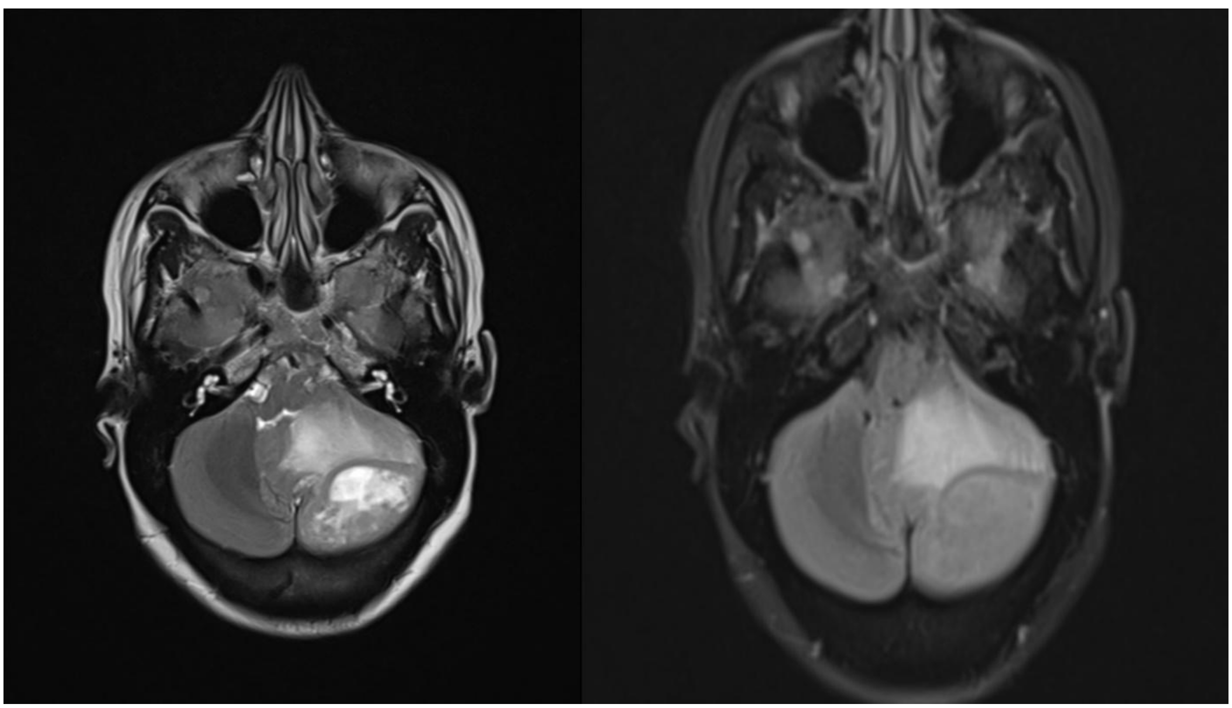


Plate. 4



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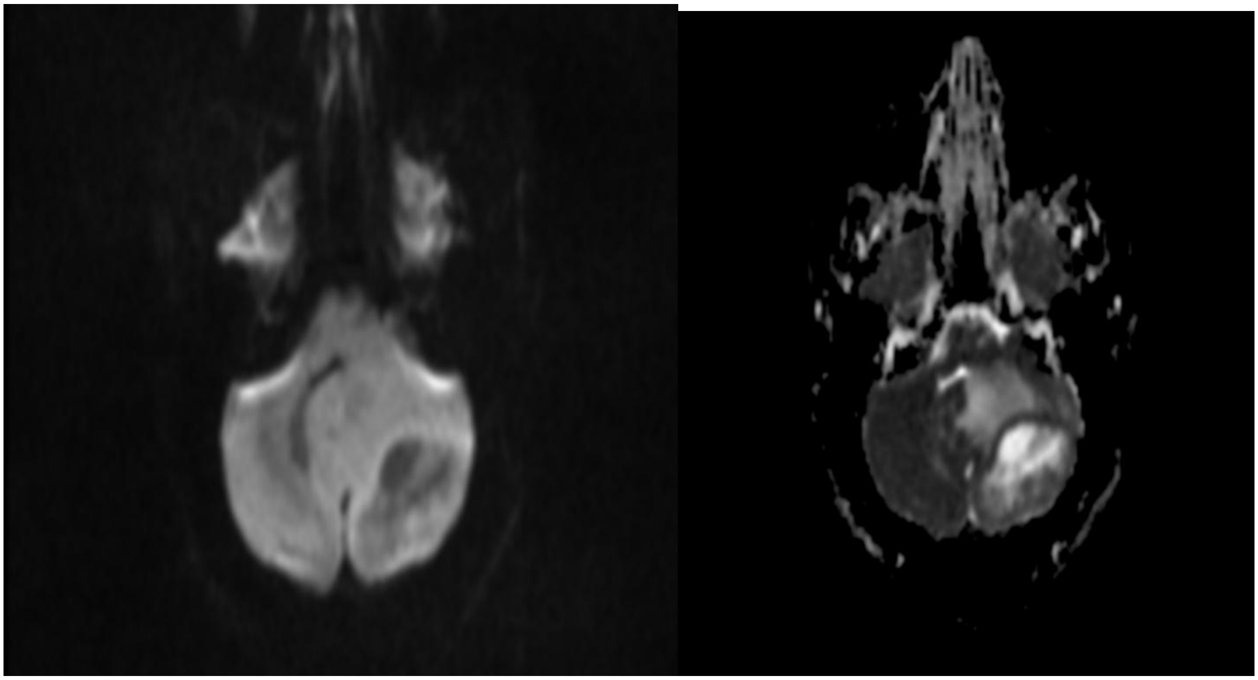
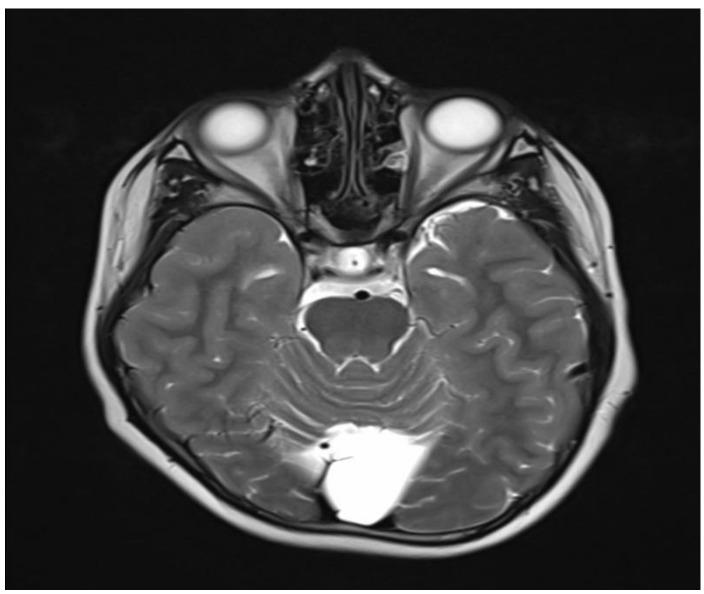


Plate 5.



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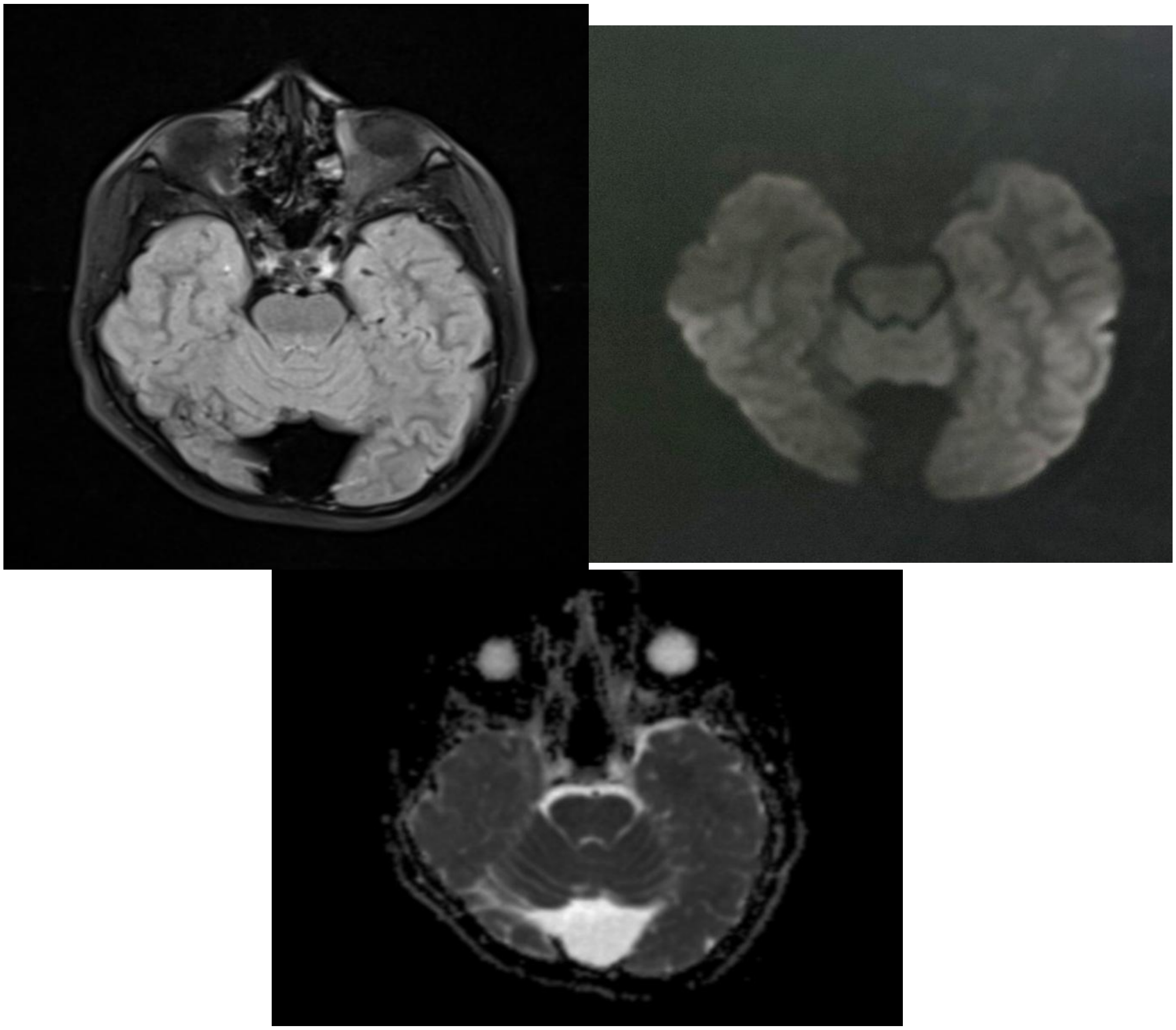
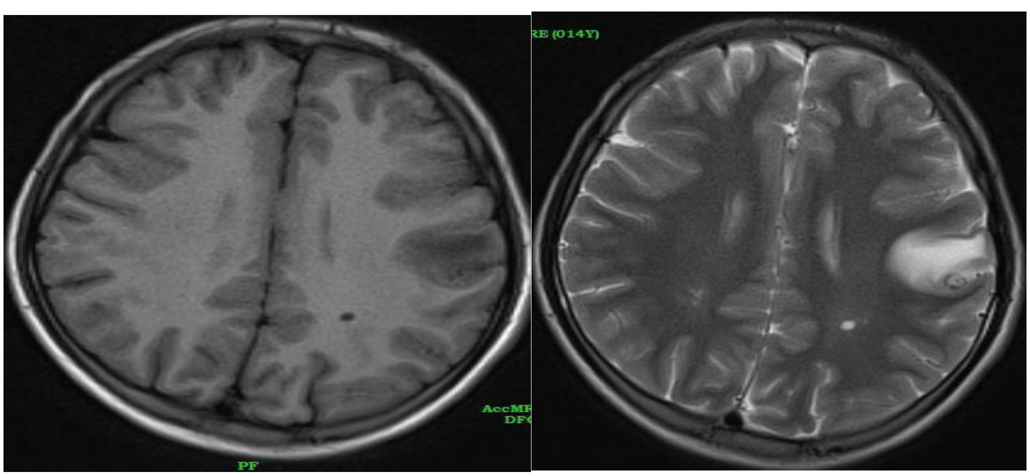


Plate. 6



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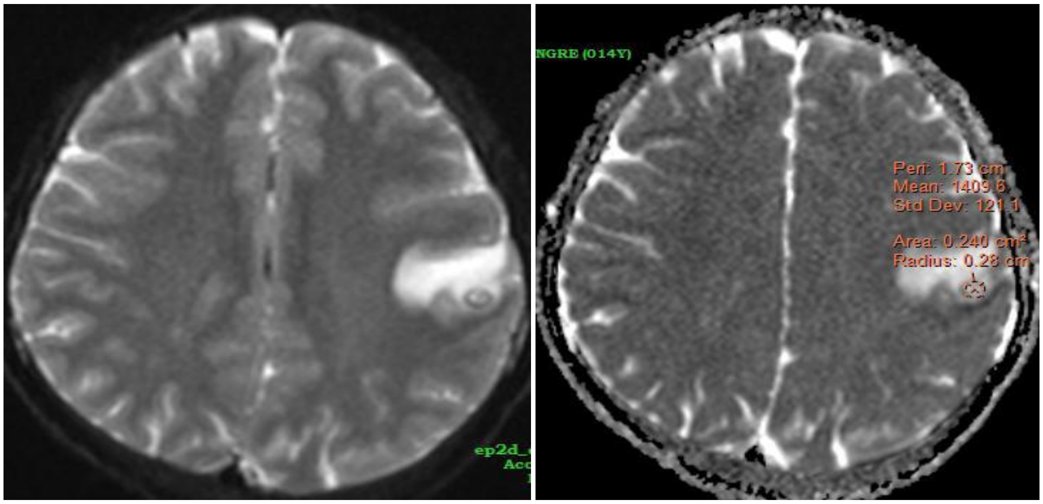

Plate. 7

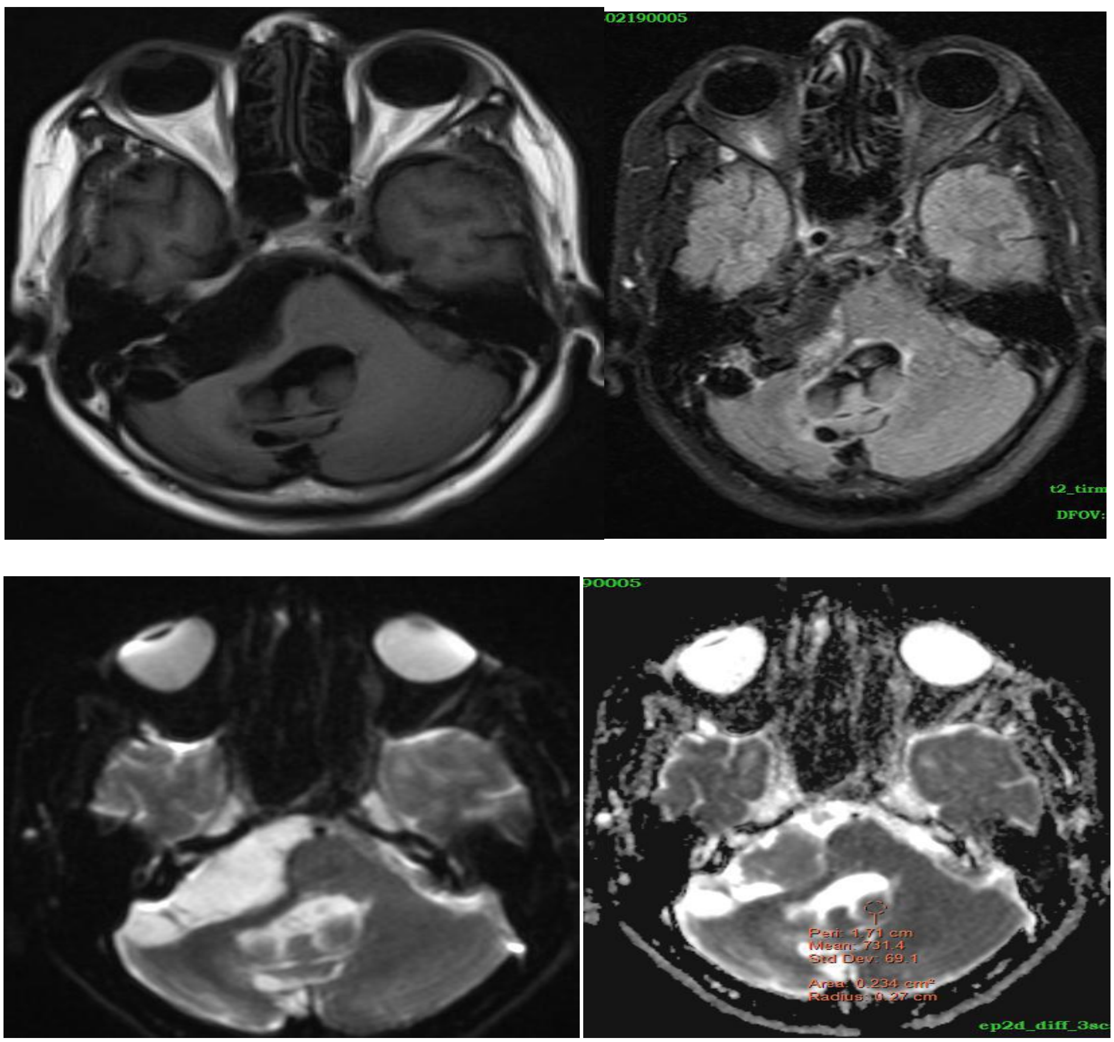

Plate. 8

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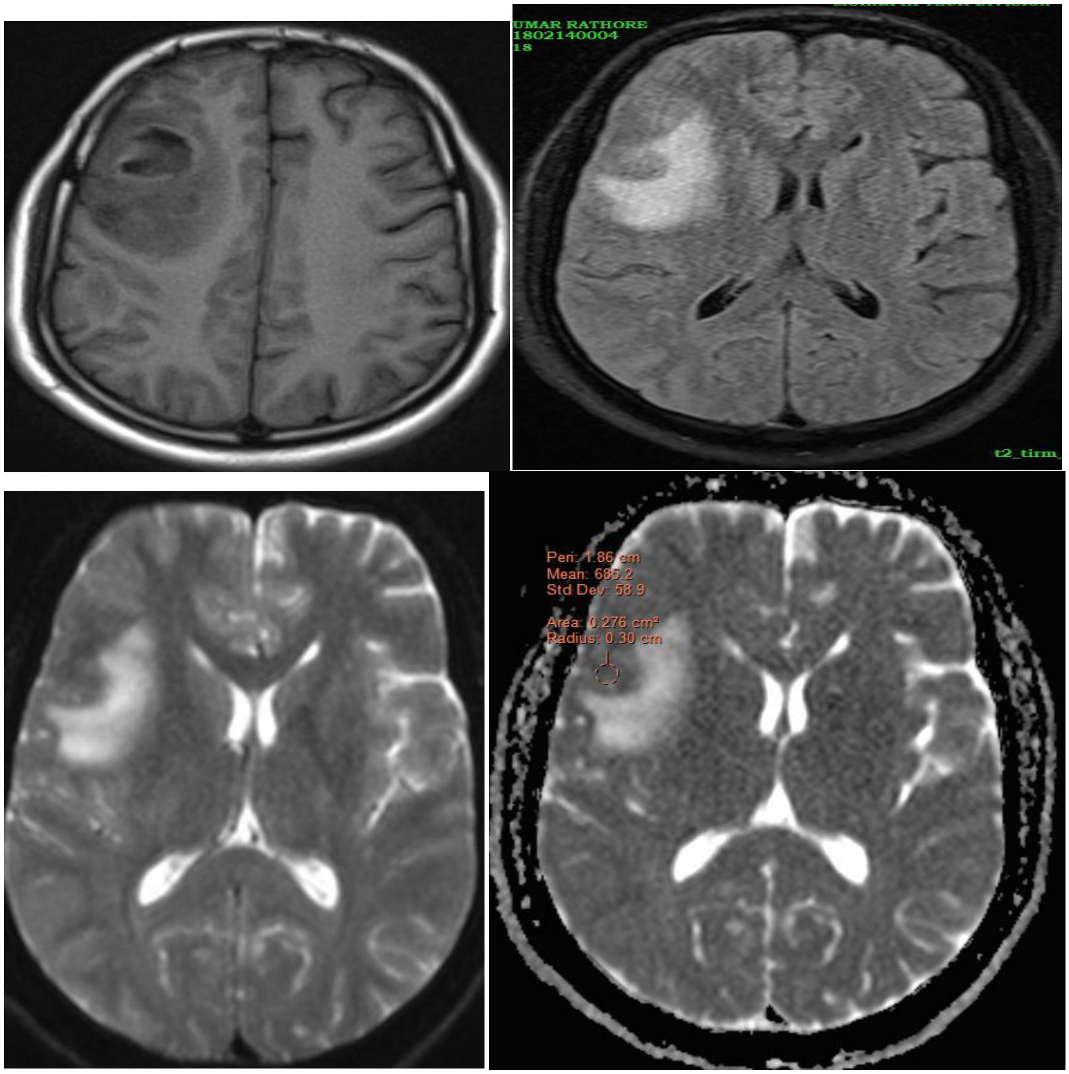
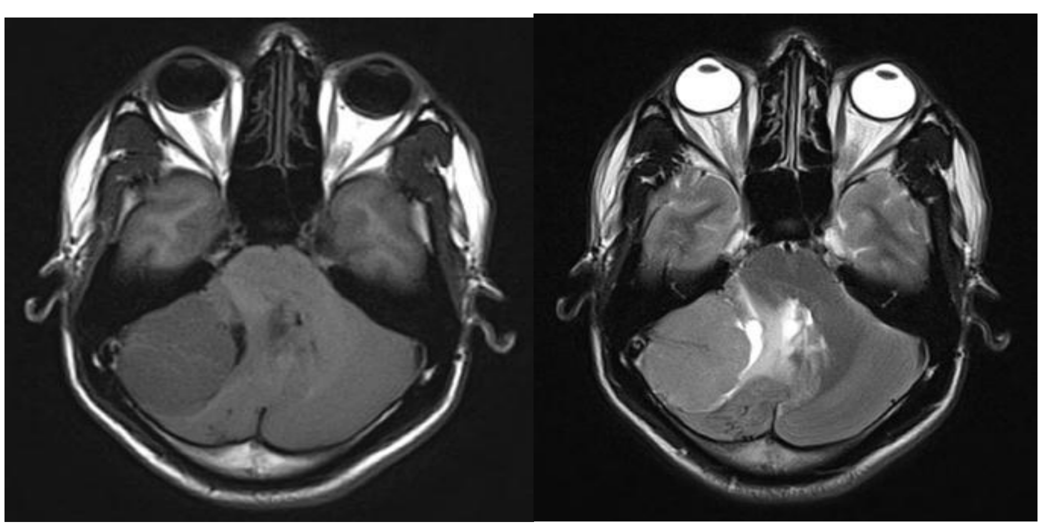


Plate. 9



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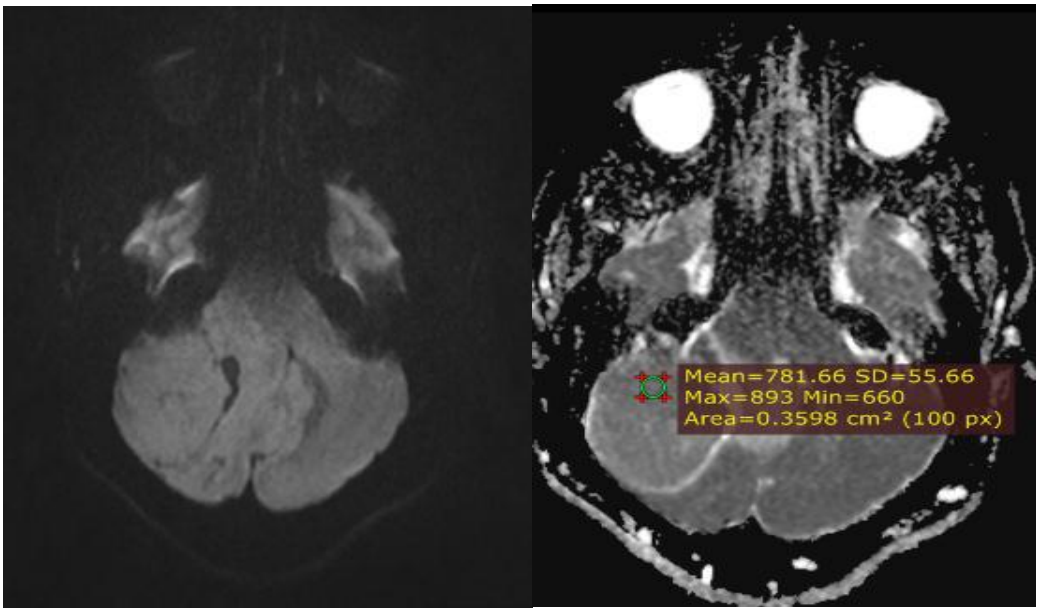
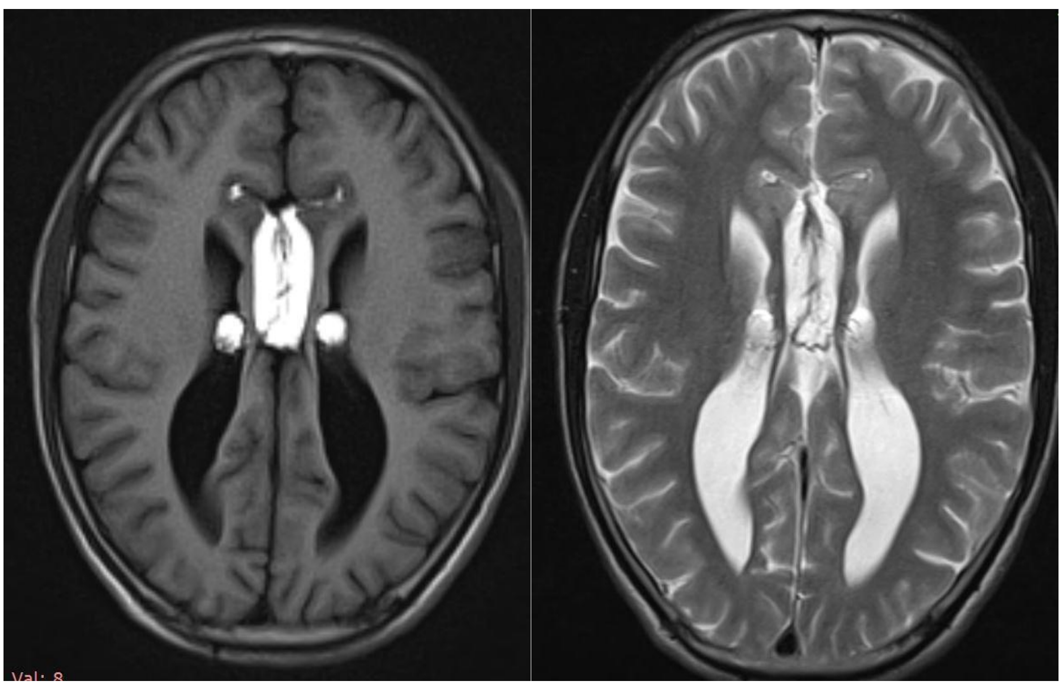


Plate. 10



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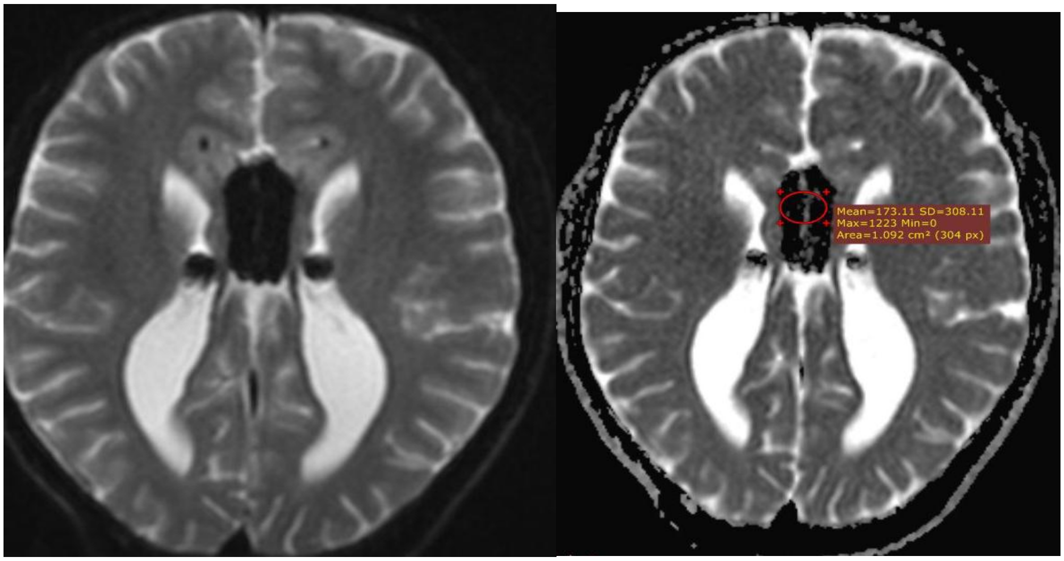

Plate. 11

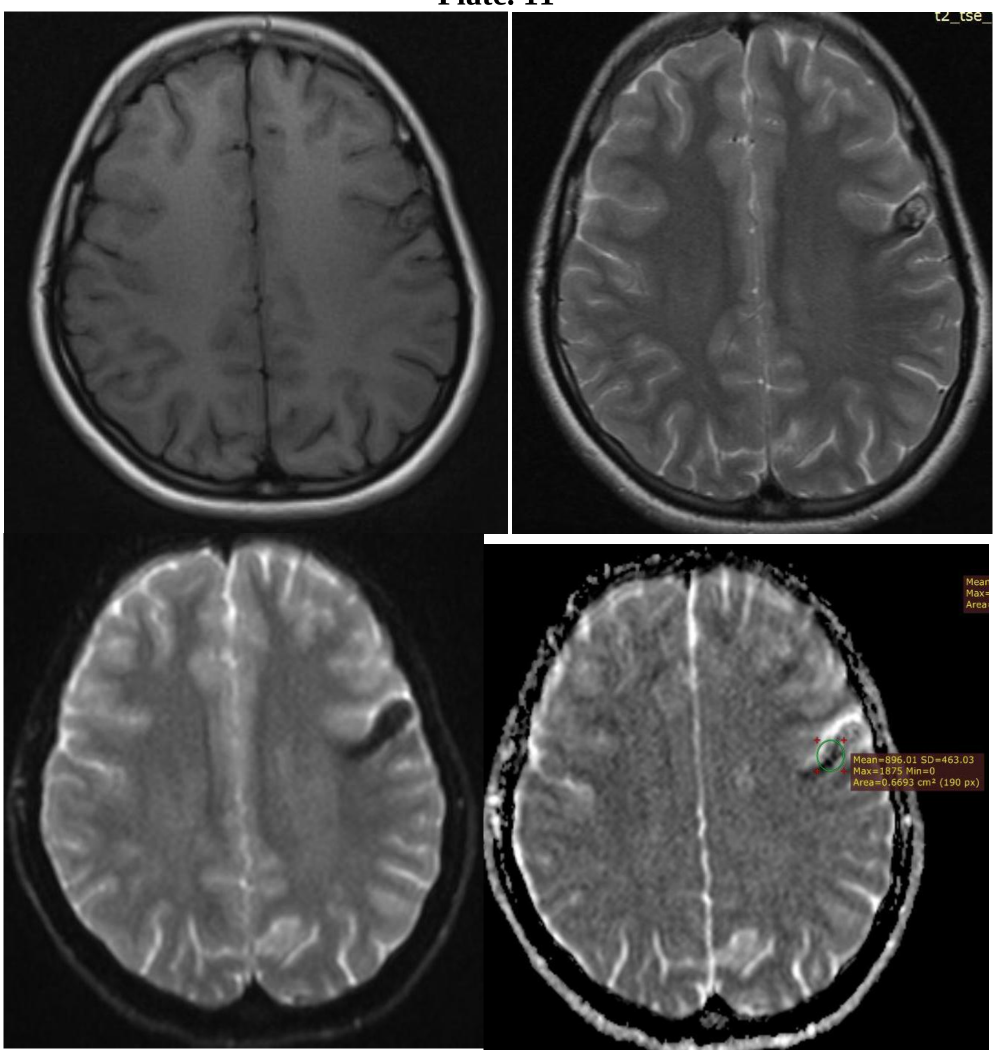

Plate. 12

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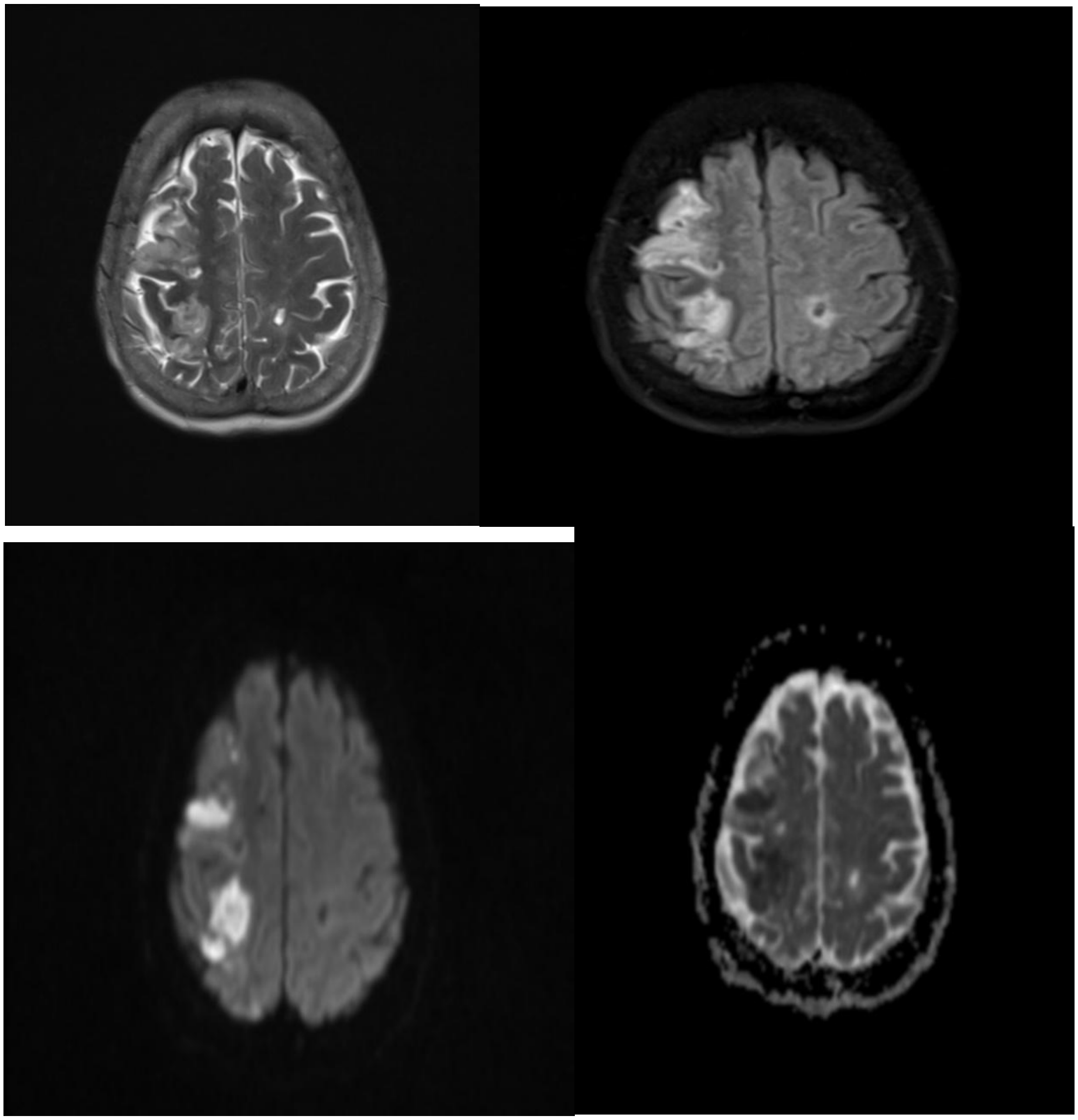

Plate. 13

4. Discussion

MRI is now an established investigating tool for the characterization of intracranial lesions. It is a favored modality over CT, because of high contrast resolution, the ability to obtain images in axial, coronal and sagittal plane, and lack of ionizing radiation. The role of imaging is no longer limited to merely providing anatomic details. Application of a diagnostic algorithm that integrates advanced MR imaging features with conventional MR imaging findings may help the practicing radiologist make a more specific diagnosis for an intracranial lesion. DWI has got a proven role in earlier detection and in documentation of extent of brain involvement in cases of cerebral ischemia. It is a technique that acquires an image during a single breath-hold and does not require contrast medium. According to literature the intracranial lesions along with ischemic lesions also show characteristic findings on diffusion weighted imaging. Many studies have shown the added advantage of diffusion weighted imaging in differentiating various intracranial lesions, both in adults as well as pediatric age group. Our thesis is based on the hypothesis that

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information provided by DWIs and ADCs is useful to diagnose intracranial lesions better than the conventional MRimaging.

A total of 50 patients having Intra Cranial Lesions and fulfilling inclusion and exclusion criteria, were evaluated in our study by conventional MRI sequences and DW imaging. Majority of Patients in our study were inage group 61-70 years (22%), followed by 21-30years(18%). Mean age of patient was 43years. No sex preponderance was observed in our study with 54% patients being male and 46% being females'predilection. Similar findings were reported in previous study done by Shrishail Patil et al. at Gulbarga Medical college , of the 115 patients studied, 31 (41%) were females and 84 (59%) were males. The mean age among females was 50 years and the mean age among males was 44 years (11).

Majority of lesions in our study were intra-axial(66%), whereas only 34% cases were extra-axial. Frontal Lobe was the most common site of involvement among intra-axial lesions, while lobar convexity was the most common site of involvement in extra-axial lesions.

In this study the majority of cases are of stroke which constitutes 16% of total cases. The sensitivity and specificity of DWI in the detection of acute ischemia is 100%. The difference in sensitivity of DWI and conventional MRI sequences is more in the initial time period and decreases as time progresses. Results of this study are correlated with a study done by Gonzalez et al (5) who concluded that DWI is superior to conventional MRI in the diagnosis and characterization of acute infarct. In this study restricted diffusion was noted in 100% of acute infarcts. In acute infarcts, no change was noted on T2WI. Thus DWI was noted to be superior to T2WI in detection of acute infarcts.

In chronic infarcts, abnormal signal was noted on T2WI and on DWI in all patients. Thus there was no difference in their sensitivity for later stages of infarcts. Rima et al showed that restricted diffusion is present in all patients on DW MR Studies obtained within 24 hours of the onset of symptoms, and in 94% of patients scanned after 2 weeks after ictus (4). In chronic infarcts the signal on DWI and ADC images is variable and depends on a combination of T2 signal and increased ADC values. The T2 signal is also affected by the onset of cystic encephalomalacia.

In our study patients with infective etiology accounts for 32% of cases, of which Tuberculomas (8%) and encephalitis (8%) were most common, followed by 6% cases of NCC. 3 cases (6%) of Pyogenic abscess were seen followed by meningitis (4%). The Tuberculomas showed varied signal intensity from hypointense core to hyperintense core on DWI. Central liquefaction necrosis in the tuberculoma is represented as T2 hyperintense center, while solid caseation as T2 hypointense center. Depending on the status of tuberculoma, DWI also reveals varied signal intensity. No significant difference on DWI was observed between the tuberculomas with hyper or hypointense core. Similar findings were observed by Batra A and Tripathi R.P.[(12)]. in their study of 17 focal cerebraltubercularlesionsbyDWI.GuptaR.K.andPrakashMetal[(13)] reported in their study of role of DWI in differentiation of intracranial tuberculoma and tuberculous abscess from cysticercus granulomas. While the study by Trivedi R, SaksenaS et al[(14)] titled Magnetic resonance imaging in central nervous system tuberculosis concluded that DWI shows restriction in cases of tuberculomas with liquid necrosis and no such restriction is seen in cases with solid caseation.

Out of total 50 cases, 6% cases were of NCC. All the cases in our study were of degenerating cysticercus granuloma. There was a significant difference in the ADC values of degenerating cysticercus granuloma and tuberculomas with former having higher mean ADC values. Similar findings were noted by Gupta R.K. and Prakash M et al in their study of role of DWI in

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 1468 - 1497
Received 20 January 2021; Accepted 08 February 2021.

differentiation of intracranial tuberculoma and tuberculous abscess from cysticercus granulomas. They observed ADC values in Vesicular and ADC values in degenerating stages of cysticercus cysts from the core, significantly higher than the core of tuberculomas and tuberculous abscess.

In another study by GT Santoset al(15) in 2012, they studied 48 patients of Neurocysticercosis retrospectively and established that DWI may identify the scolex, increasing diagnostic confidence for NCC. Total/subtotal DWI hyperintensity, related to the stage of the lesion, though uncommon, allows including NCC as a consideration in the differential diagnosis of lesions with reduced diffusion and ring enhancement. Encephalitis constituted 8% cases of our study population. One of the cases in our study presented early and MRI was done on 2^{nd} day and this patient showed low ADC value. Rest of the patients were subjected to MRI on 4^{th} to 7^{th} day of presentation. Kiroğlu, Y., Calli, C., Yunten, N. et al.(16) in 2006 in their study titled diffusion weighted MR imaging in viral encephalitis, quantitatively evaluated DWI of the encephalitic lesions in 18 patients and found significantly low ADC values in early presenters due to cytotoxicedema,followedbyincreasedADCvaluesinlatestagesas cytotoxic edema is replaced by vasogenic edema. They concluded that DWI is superior to other conventional diagnostic MR sequences in the detection of early viral encephalitic lesions and depiction of the lesion borders and, in combination with other sequences, DWI may contribute to the determination of the disease phase. In another study Serner RN.(17) concluded that diffusion imaging appears to be a promising sequence to monitor the changes in the brain tissue in herpes encephalitis, and in other infections as well with respect to restriction of movement due to cytotoxic edema or relatively high-motion of water molecules due to vasogenic edema, providing data on the severity of thedisease.

Abscesses constituted 6% of cases in our study population, all were pyogenic.The lower ADC values in abscesses are reported to be due to presence of intact inflammatory cells, bacteria and pus. In 2002 Chang et al.(18) conducted study on Diffusion-weighted MRI features of brain abscess and cystic or necrotic brain tumors: comparison with conventional MRI. Eleven consecutive patients with brain abscesses and 15 with cystic or necrotic brain gliomas or metastases were enrolled. Increased signal was seen in all of the pyogenic abscess cavities to variable degrees on DWI. In vivo ADC maps showed restricted diffusion in the abscess cavity in all pyogenic abscesses. All cystic or necrotic tumors but one showed low signal intensity on DWI and their cystic or necrotic areas had high ADC values. Post contrast T1WIs yielded a sensitivity of 60%, (PPV) of 52.94%, and a negative predictive value (NPV) of 33.33% in the diagnosis of necrotic tumors. DWI yielded a sensitivity of 93.33%, a specificity of 90.91%, a PPV of 93.33%, and a NPV of 90.91%. They concluded that with some exceptions, DWI is useful in providing a greater degree of confidence in distinguishing brain abscesses from cystic or necrotic brain tumors than conventional MRI and seems to be a valuable diagnostic tool. Reddy JS et al.(19) in their study considered cystic lesions with ADC values less than 0.9 +/- 0.13 x 10^{-3} as abscess and observed high sensitivity and specificity of DWI for differentiation of brain abscesses from non abscesses. They found sensitivity of DWI 96%; specificity 96%; positive predictive value 98%; negative predictive value 92%; and accuracy of the test96%.

A study was conducted by Garg et al.(20) at Haryana published in 2016 for studying intracranial ring lesions on DWI. The results showed that for diagnosing tuberculoma, sensitivity and specificity of the MRI+DWI was 87.5% and 100% respectively. For GBM, sensitivity and

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 1468 - 1497
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specificity of the MRI+DWI was 100% and 100% respectively. For metastasis, sensitivity and specificity of the MRI+DWI was 100% and 100% respectively. For abscess, sensitivity and specificity of the MRI+DWI was 100% and 93.1% respectively. For NCC, sensitivity and specificity oftheMRI+DWIwas100%and100%respectively.Atotalof19cases of intracranial neoplastic lesions were studied in present study accounting for 38% of the cases, of which Metastasis (12%) and Meningiomas (10%) were most common. 6% cases were of Schwanoma. High grade gliomas were 2% and Low grade gliomas were 4% . One case of lipoma and one case of cavernoma was also included in the study.

Metastases showed varied ADC values depending on their nature. Y Hayashida et al[21] in their study, Diffusion-weighted Imaging of Metastatic Brain Tumors: Comparison with Histologic Type and Tumor Cellularity observed that the mean ADC values of well differentiated adenocarcinomas was significantly higher than that of poorly differentiated adenocarcinomas and that of tumors of other histologic types. They concluded that DWI may predict the histology of metastases and their ADC reflect tumor cellularity. While Jung WS et al in their study, Diffusion-Weighted Imaging of Brain Metastasis from Lung Cancer: Correlation of MRI Parameters with the Histologic Type and Gene Mutation Status suggested that DWI parameters for the solid components of brain metastasis from lung cancer are not correlated with their histology. Meningiomas constituted 10% of the cases in our study population. The mean ADC values of these lesions were found to be high.

In our study most of the meningiomas were typical smoothly marginated benign. Hakyemez et al[22] in their study, The contribution of diffusion-weighted MR imaging to distinguishing typical from atypical meningiomas analysed 39 patients with meningioma and found that the mean ADC value of benign tumors was significantly higher than the mean ADC value of atypical/malignant meningiomas. . Filippi CG et al.[23] in their study, Appearance of Meningiomas on Diffusion-weighted Images: Correlating Diffusion Constants with Histopathologic Findings. They suggested meningiomas with lower ADC values tended to be malignant or highly atypical. Nagar VA et al[24] in their study of Diffusion-Weighted MR Imaging: Diagnosing Atypical or Malignant Meningiomas and Detecting Tumor Dedifferentiation, also found that mean ADC of atypical/malignant meningiomas was significantly lower compared with benign meningiomas. In our study 6 % of the cases were of Schwanomas. The mean ADC value of the schwanomas were high. Donia MM et al[25] in their study of “Intracranial neoplastic lesions ofthe trigeminal nerve: How MRI can help” found mean ADC values of schwanomas to be 95 +/- 0.6($\times 10^{-3}$ mm^2/sec (High).

High grade and Low grade gliomas were 4% each. High grade gliomas revealed lower ADC values in comparision to low grade gliomas in our study. Low ADC values within the tumor represents increased cellularity in the region. Klisch J et al.[26] in year 2000 done study on three pediatric patients and stated that diffusion-weighted imaging (DWI) can be used to show the solid portion of the tumor preoperatively and to monitor postsurgical recovery. KinukoKono, Yuichi Inoue, Keiko Nakayama et al[27] in 2001, in their study titled The role of diffusion weighted imaging in patients with brain tumors, established that DWI imaging with ADC mapping may predict the degree of malignancy of brain tumors. They found that the ADCs were higher in grade II astrocytomas than in glioblastomas Higano et al.[28] in their study “Malignant astrocytic tumors: clinical importance of apparent diffusion coefficient in prediction of grade and

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prognosis," showed minimum ADC value instead of mean ADC value of the tumor is more effective in tumor grading.
One case of lipoma and one case of cavernoma was also included in the study.The lipoma showed signal drop out on DWI and ADC map. As the lipomas has got classic appearance on convetional MR sequence, No significant literature is available on DWI of lipomas. The Cavernoma showed mixed signal intensity with predominantly low signal areas. The low signal area on DWI assumed to reflect the hemosiderin or susceptibility effect and blood oxygen level dependent (BOLD)effect by the deoxyhemoglobin and T2 black out effect.
Arachnoid cyst(12%) were the commonest noninfective space occupying lesions. They showed markedly high mean ADC values except for one, which was actually an epidermoid cyst having low ADC value with restricted diffusion. Differentiation between epidermoid/arachnoid cyst was inconspicuous on conventional MR sequences. The markedly low ADC values in epidermoid cyst isdue to it's internal architecture, which is often composed of desquamated epithelial keratin and cholesterol crystals. A study conducted by Annet L et al(29) in 2002 on six surgically proven epidermoid cysts performed ADC calculation from T2-weighted DW- EPI-SE data within the ECs and within the deep white matter and cerebrospinal fluid (CSF) as references concluded that all ECs displayed highest signal intensity on the DW trace images and were markedly hypointense to CSF and were iso or slightly hyperintense to gray and white matter on ADC maps. Whereas arachnoid cysts were marked as hyperintense with ADCs similar to those of CSF. In another study done byBerguiM,ZhongJ,BradacGB,SalesS(30)in2001,titleddiffusion weighted images of intracranial cyst like lesions, they established that diffusion restriction is shown by epidermoid cysts and no diffusion restriction is showed by arachnoid cysts and diffusion weighted imaging can be a useful tool to differentiate between the lesions.
There was only one case of demyleinating disease that was of central pontine myelinolysis which showed restriction of diffusion which correlated well with the study done previously by Ruzek et al(31) in 2004 which showed that cases of central pontine myelinolysis showed restricted diffusion in central pons within 24 hrs of onset of tetraplegia before the signs manifest at conventionalimaging. DWI is now widely available and is applied in evaluation of almost all the cases subjected to MRI. But in most of the circumstances only visual impression of restriction or no restriction is looked for. In our study we found that most of the intracranial lesions showed no restriction in comparision to gray matter-white matter of the brain, but most of them had characteristic mean ADC values. Other investigators also found similar or slightly different ADC values in the various intracranial lesions. The use of characteristic mean ADC values in combination with location and conventional MR morphology may be of significant help in differential diagnosis of various intracranial pathologies. We propose that quantitative DWI would help better in the evaluation of intracranial lesions rather than simple visual impression of restriction/ norestriction.

5. Conclusion

Diffusion weighted imaging revealed significantly different ADC values among different intracranial lesions. High grade gliomas having diffusion restriction with reduced ADC values in comparison to Low grade gliomas. Thus, diffusion weighted imaging and the accompanying ADC values can add useful information to the morphological details provided by contrast enhanced MRI. This may directly affect patient management strategies and may have great prognostic implications. DWI has a high diagnostic potential.

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Ethical approval: The study was approved by the Institutional Ethics Committee

6. Conflict of Interest

The authors declare no conflict of interest.

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