Study of Brain Mass Lesions by MRI- On Special Sequences

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Abstract

Background: *The purpose of this study was to assess the role of Diffusion-weighted magnetic resonance imaging (DW-MRI) and apparent diffusion coefficient (ADC) values in the evaluation of different benign and malignant brain mass lesions with his to pathological correlation.*

Material /Methods: *We retrospectively reviewed 50 MR examinations of patients who were referred to Department of Radio Diagnosis, BMC&RI, Bangalorefor intracranial mass lesion evaluation with MRI. All of them had undergone conventional MRI examination with SIEMENS AVANTO 1.5 T scanner and we determined ADC values and signal intensities on DWIs.In all patients with contrast-enhanced tumors, ROIs were placed in theenhanced region. In patients with non-enhancing tumors, ROIs were placed in the solid part of thelesion. We also evaluated the correlation between ADC values and cellularity in the mass lesions. Additional clinical details and histopathological findings were correlated with the DWI and ADC findings for radiologic-pathologic concordance.*

Results: *A positive correlation was found in the comparison of mean ADC values for high grade gliomas (1.19×10^{-3} mm^2/s ±0.2) and metastasis (0.833×10^{-3} mm^2/s ±0.2), low grade gliomas (1.34×10^{-3} mm^2/s ±0.2) and medulloblastomas ($0.68\times10^{-3}mm^2/s$ ±0.075), as well as for in epidermoid cyst and necrotic areas in malignant tumors. However, there is some overlap was found in the ADCs of low grade gliomas and high grade gliomas.*

Conclusion: *ADC values cannot be used in individual cases to give specific diagnosisreliably. Although the ADCs of patients with low grade and high grade gliomas overlapped, the combination of routine image interpretation and ADC had a higher predictive value. The ADCs of glioma, metastasis and meningioma are related to tumor cellularity. We believe that DWIs and ADCs can provide information useful to diagnose brain mass lesions that cannot be obtained with conventional MR imaging.*

Keywords: *apparent diffusion coefficient – ADC, brain mass lesions, diffusion-weighted imaging – DWI, magnetic resonance.*

I. INTRODUCTION

A conventional MRI examination allows for visualization of a mass lesion, and provides us with information on mass location, its homogeneity and on signal intensity, the presence of perilesional edema and degree of contrast enhancement. Among the brain mass lesions, differentiation between low and high-grade tumors based on MRI is still very difficult. Traditional tumors of high grade are very heterogeneous, which results from the presence of necrotic and/or hemorrhagic regions, an extensive vascular edema, strong enhancement and mass effect. However, these signs are notalways present. Sometimes, low-grade tumors show features typical for more malignant tumors.[1, 2]Similarly differentiation between intracerebral necrotic tumors and cerebral abscesses is frequently impossible with conventional MR imaging.

Diffusion-weighted imaging (DWI) is a very well-knownand a widely used method, present in a routine MRI protocol, and allowing for evaluation of a normal brain tissue orits lesions caused by ischaemia, injury, proliferation, multiple sclerosis, or abscess.[3–7]

Our hypothesis was that diffusion-weighted images (DWIs) and mass lesionapparent diffusion coefficient (ADC) could provide additional useful information in the differential diagnosis of patients with brain mass lesions and differentiation between intracerebral necrotic tumors and other benign cystic lesions.

The aim of the work was to evaluate the usefulness of ADC in differentiation of various brain mass lesions and also establishing the grade of brain tumors with direct information on cellular density of tumors and differentiation of benign cysticand malignant necrotic areas.

II. OBJECTIVES OF THE STUDY

1. To assess the role of DW-MRI in the evaluation of different mass lesions of brain with histopathological correlation.
2. To evaluate the role of ADC values in characterisation and differentiation of benign and malignant mass lesions of brain.

III. MATERIALS AND METHODS

The study design was a cross sectional study and it was done in patients who were referred to Victoria Hospital attached to Bangalore Medical College and Research Institute, Bangalore between December 2012 to November 2014.The study sample size was fifty.

A. *Inclusion criteria*

- Patients referred with features suggestive of brain masses based on the clinical data or other imaging modality.
- Cases were included irrespective of age / sex.

B. *Exclusion criteria*

- Contraindications to MRI studies, such as patients with pacemakers, metallic implants, aneurysmal clips.
- Claustrophobia or anxiety disorders exacerbated by MRI.
- Not willing to give consent.

C. *Methods*

Brain MRI results of 50 patients with histologically verified or clinically diagnosed brain mass lesions were subjected to analysis. They ranged in age from 2 to 72 years (mean, 43.5 years). The examinations were performed with a 1.5T scanner, an 8-channel surface head coil. The examination protocol included the following sequences and images: TSE T2WI (3920/102/1), FLAIR (2500/9000/111/1) [IR-inversion time/TR/TE/excitations] and SE T1WI (488/10/1) [TR-repetitiontime/TE-echo time/excitations]), carried out in three planes, before and after contrast medium administration (in a standard dose). Matrix: 256×256 and 256×192, field of view: 220–230 mm, slice thickness: 3–5 mm, slice interval of 30%.
DWI was performed before contrast medium administration; sequence parameters – TR/TE-2300/73, field of view: 230 mm, matrix: 128×128, slice thickness: 5mm, slice interval: 1 mm, b-values 0/500/1000 mm^2/s.The DWIs were acquired by using the echo-planar imaging (EPI) sequence that combined the motion-probing gradient (MPG) before and after the 180^o pulse with EPI readout, and fat was suppressed by placing a frequency-selective RF pulse before the pulse sequence.

ADC was measured with a manual placement of ROIs in the solid part of the lesion. The solid part of the lesion was identified on the basis of a detailed analysis of T1-weighted images after contrast administration and T2-weighted images, including FLAIR sequence. In case of enhancing tumors, ROIs were placed in the enhanced region, while in case of non-enhancing tumors; ROIs were placed in the solid part of the lesion, identified on the basis of a FLAIR image.

The measurements were taken 3 times and included calculation of a mean value for each lesion. ROI size was 5 pixels (approx. 50–100 mm^2).The measurements did not include cystic, necrotic, hemorrhagic areas, or edema surrounding the tumor.

IV. RESULTS

Thirteen gliomas (five high grade glioma-WHO III/IV and eight low grade glioma WHO- I/II), 10 metastatic tumors, 9 meningiomas, 7 schwanommas, 3 abscess, 3 epidermoid cyst 3 hemangioblastomas and 2 medulloblastoma (WHO IV) were included in our study.

Among high-grade tumors, ADC values ranged from 1.012 to 1.315 $X10^{-3}mm^2$ /sec. In low-grade tumors, ADC values ranged from 1.09 to1.78×10^{-3} mm^2 /s. Among metastasis, ADC values ranged from 0.56 to 1.074×10^{-3} mm^2 /s.In meningioma, ADC values ranged from 0.72 to 1.14×10^{-3} mm^2 /s. In schwanomma, it was 0.877–1.32×10^{-3} mm^2 /s. In the group of medulloblastomas, it was $0.51–0.86\times10^{-3}$ mm^2 /s. In hemangioblastomas, it was $0.978–1.429\times10^{-3}$ mm^2 /s. Among benign cystic lesions in epidermoid cyst, ADC values ranged from 0.79 to 0.98×10^{-3} mm^2 /s and in abscess it was $0.425–0.603\times10^{-3}$ mm^2 /s. (Table 1).

A positive correlation was foundin the comparison of mean ADC values forhigh grade gliomas (1.19×10^{-3} mm^2 /s ±0.2) and metastasis (0.833×10^{-3} mm^2 /s ±0.2), low grade gliomas (1.34×10^{-3} mm^2 /s ±0.2) and medulloblastomas ($0.68\times10^{-3}mm^2/s$ ±0.075), as well as for in epidermoid cyst and necrotic areas in malignant tumors. However,there is some overlap was found in the ADCs of low grade gliomas and high grade gliomas.

V. DISCUSSION

MR diffusion imaging has been used to study water mobility in normal brain tissue, cerebral infarction, multiple sclerosis, gliomas, and brain abscesses and to differentiate between arachnoid cysts and epidermoid cysts and other diseases. [6, 9]Preoperative differentiation of brain mass lesions is very important, due to different therapeutical approaches and prognosis.

Differentiation of mass lesions like tumors with a standard MRI, on the basis of such criteria as: signal intensity of the mass lesion, presence of cysts, necrotic regions, peri-tumoral edema, as well as the degree of contrast enhancement or its lack, is unreliable or even impossible.[10] Both in the literature and in our material, the malignant mass lesions were not always getting enhanced after contrast administration, the peri-tumoral edema was not

always present, and the cysts and/or necrotic regions were present in both malignant, and in benign tumors.[10]That is why; it is required to search for other, modern imaging methods, which would be helpful in the differentiation of the brainmass lesion.

On imaging studies, malignant gliomas usually are enhanced after intravenous contrast injection and show peritumoral edema, whereas, except for pilocytic astrocytoma and giant-cell astrocytoma, low-grade gliomas usually show little to no abnormal enhancement or peritumoral edema. Differentiation of these two types of tumors occasionally may be difficult, because low-grade astrocytomas also may show abnormal contrast enhancement and peritumoral edema. In fact, abnormal enhancement was noted in three of eight patients with low-grade astrocytoma in our study, and peritumoral edema was found in four patients.

A standard differentiation of brain tumors with T2-weighted images shows some differences in signal intensity of the lesions. FLAIR sequence is less useful in the differential diagnosis.Astrocytomas reveal higher signal intensity in T2-weighted images, but not as high as the cerebrospinal fluid. Pilocytic astrocytomas frequently show much higher signal intensity than medulloblastomas. This concerns both the cystic, and the solid part of astrocytomas. Differences in signal intensity are directly connected with histological structure of the tumors. Malignant tumors with high mitotic activity are hypercellular and reveal lower signal intensity than benign tumors with a looser structure.

In typical medulloblastomas, the solid part of the tumor is isointense in comparison to the grey matter. This is connected with a higher ratio between the nuclei and the cytoplasm in tumor cells, i.e. reduction of free water molecules in this region. The observed tumor heterogeneity on the other hand is the result of formation of small cysts and calcifications.

Diffusion-weighted imaging is a well-known and a commonly used sequence which allows for visualization anddifferentiation of: ischemic foci in their early phase, dermoid cysts, inflammatory lesions, and proliferative processes of the CNS.

This method depends on the degree of free diffusion ofwater molecules in the examined environment. The extracellular space is characterized by a relative isotropy and arelatively high diffusion coefficient, as in case of the cerebrospinal fluid present in brain ventricles. The intracellularspace reveals anisotropy of a different degree, dependingon the number and density of the cell membranes. On thebasis of the data obtained from measurements carried outin at least two sequences with a different degree of coefficient b (different amplitude and different time of gradient),ADC images are construed, with their values reflecting thedegree of diffusion in a given region.

Due to the differences in diffusion rate of water moleculesdepending on the environment (serum, mucus, pus, solidtissue, etc.), there appeared many publications aiming toevaluate the differences in cellular density of mass lesions, and indirectly also in mitotic activity of the tumors, with the use of diffusion degree within the lesion. In the previously published reports it was found that an increase in cellular density leads to higher signal intensity in DWI images and a lower effective diffusion coefficient on the ADC map. Published reports have confirmed an inverse relation between the cellular density and the ADC value[5, 11- 13] In our report, we analyzed various types of brain mass lesions and establish the role ADC in characterisation and differentiation of benign and malignant brain mass lesions as well as differentiation between intracerebral necrotic tumors and other benign cystic lesions.

On the basis of ADC evaluation in the presented group of patients, we showed a possibility of differentiation between high grade glioma and metastasis, pilocytic astrocytomas and medulloblastomas, as well as necrotic tumors and benign cystic lesions like abscess, epidermoid cyst and arachnoid cyst.

ADC coefficient values for different types of tumors in our patients were similar to the results of the previously published reports.[11, 14, 15] In most of the cases, ADC was significantly decreased in high grade tumors of grade III and IV, and increased in benign tumors of grade I (WHO).Mean diffusion rate in the solid part of pilocytic astrocytomas amounted in our study to 1.342×10^{-3} mm^2 /s, and to 0.686×10^{-3} mm^2/s for medulloblastomas. Similar data were published in 2006, and the mean ADC of tumors in the quoted article amounted to 1.65±0.27×10 –3 mm 2 /s and 0.66±0.15×10 –3 mm 2 /s, respectively.[15]

We found that ADC values cannot be used in individual cases to differentiate tumor types reliably. Although the ADCs of grade II astrocytoma and glioblastoma overlapped somewhat, the combination of routine image interpretation and ADC had a higher predictive value. Our results indicate that lower ADCs suggest malignant glioma, whereas higher ADCs suggest low-grade astrocytoma. These results agree with those of previous reports.[8] Although no patients with anaplastic astrocytoma were included in our study, we expect that the ADCs of this type of tumor (a grade III astrocytoma) will be intermediate between those of glioblastoma and grade II astrocytoma.

In our study, we found ADC measurements to be useful in cases in which a conventional MR was ambiguous or revealed features of infiltration of adjacent structures. An example may be a 42-year-old

boy with a tumor located in the pineal region, who revealed quite homogeneously increased signal intensity. Standard MRI showed an ill-defined infiltrative lesion in the pineal region causing obstructive hydrocephalus. However, ADC measurements showed a mean diffusion rate within the tumor typical for pilocytic astrocytoma. This was confirmed with a histopathological examination (Figure 1).

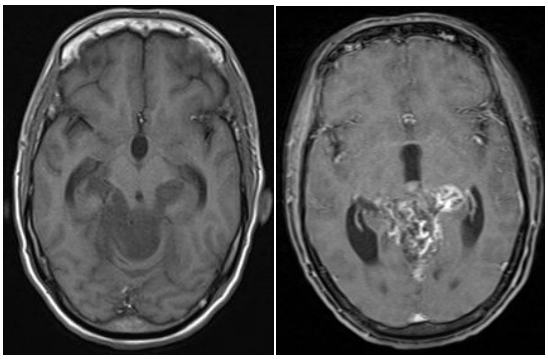
Our results of diffusion examined in brain mass lesions showed that a low mean ADC value is the most frequent in high-grade tumors, while a high one is more indicative of benign tumors.

VI. CONCLUSION

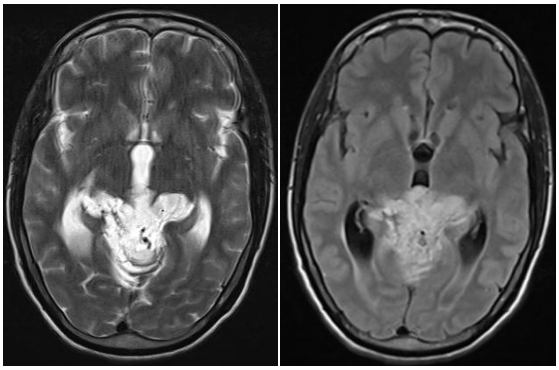
In conclusion, ADC values cannot be used in individual cases to give specific diagnosis reliably. Although the ADCs of patients with low grade and high grade gliomas overlapped, the combination of routine image interpretation and ADC had a higher predictive value. The ADCs of glioma, metastasis and meningioma are related to tumor cellularity. We believe that DWIs and ADCs can provide information useful to diagnose brain mass lesions that cannot be obtained with conventional MR imaging.These results are consistent with previous publications of other authors. [5, 16, 17]

Table 1.Values of ADC in brain tumors in our group of patients.

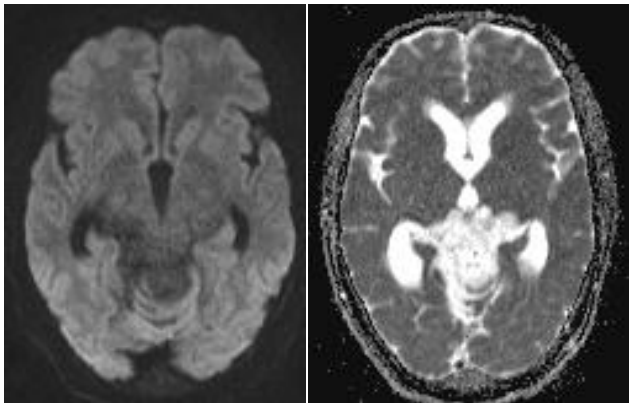
Tumor type	No of patients	Age range (years)	ADC Range ($X10^{-3}mm^2/sec$)	Mean ADC ($X10^{-3}mm^2/sec$)
High grade glioma	5	11-64	1.012-1.315	1.193
Low grade glioma	8	12-62	1.090-1.788	1.342
Metastasis	10	33-72	0.565-1.074	0.833
Meningioma	9	39-63	0.720-1.147	0.874
Schwanomma	7	24-60	0.877-1.320	1.039
Hemangioblastomas	3	18-48	0.978-1.429	1.220
Medulloblastoma	2	7-18	0.511-0.861	0.686
Epidermoid cyst	3	33-50	0.797-0.984	0.910
Abscess	3	2-41	0.425-0.603	0.503



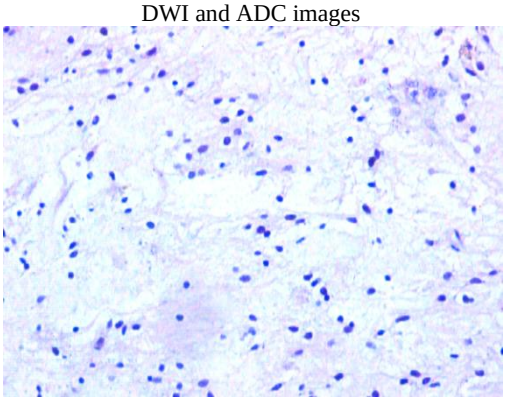
T1 and T1 Contrast



T2 and FLAIR



DWI and ADC images



Histopathology slide: HPE shows sheets of bipolar pilocytic astrocytes with rosenthal fibres and reactive vessel proliferation.

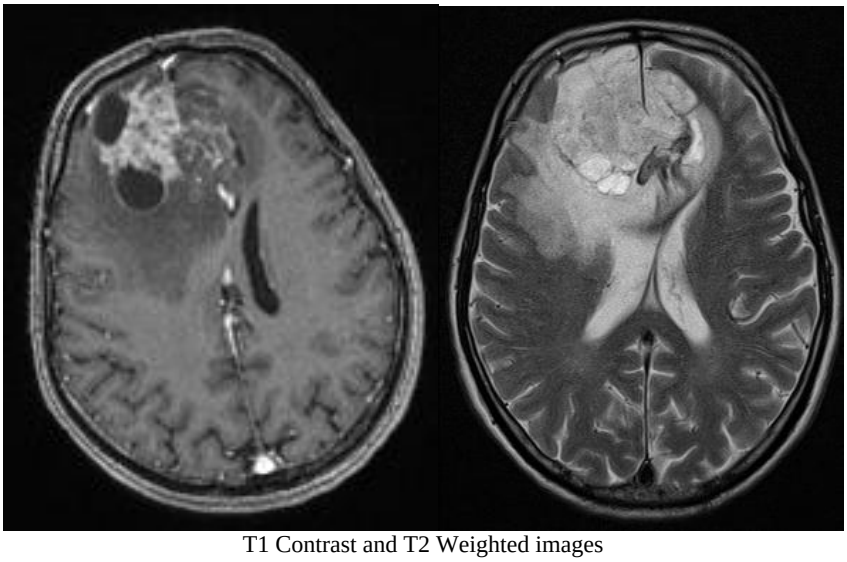
Figure 1: T1, T2, FLAIR, T1 Contrast,DWI ADC mappingandHistopathology

42 years male presented with difficulty while walking since six months, he also c/o swaying while walking, diminished vision and headache since 2 months.

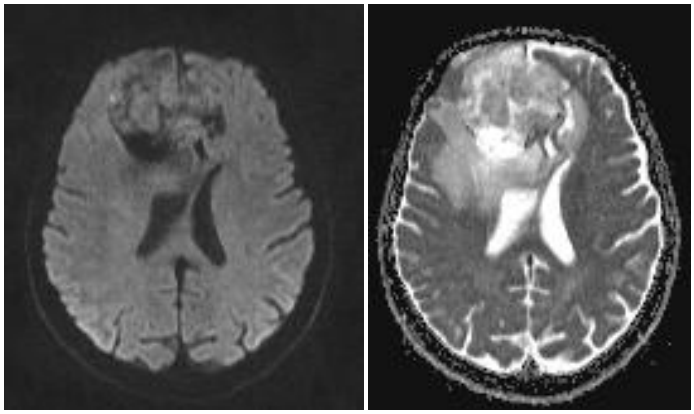
Ill-defined infiltrative heterogeneously enhancing T1 hypointense, T2/Flair hyper intense lesion involving the pineal gland & tectal plate region causing obstructive hydrocephalus.

DWI and ADC map (mean ADC: 1.788×10^{-3} mm^2/s)

Diagnosis: Post third ventricular tumor- Pilocytic Astrocytoma.



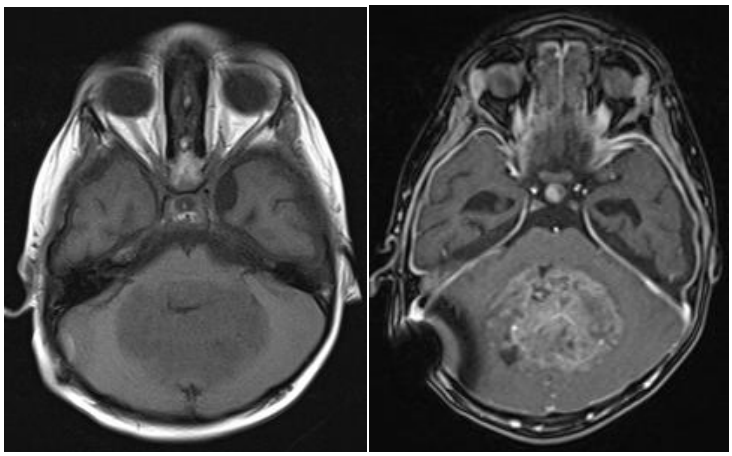
T1 Contrast and T2 Weighted images



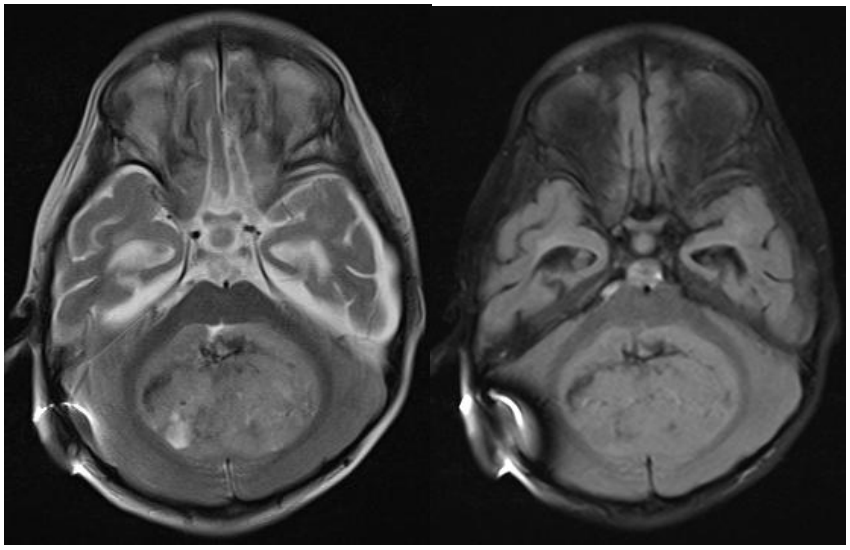
DWI and ADC images

Figure 2: T1 Contrast, T2 Weighted,DWI and ADC mapping

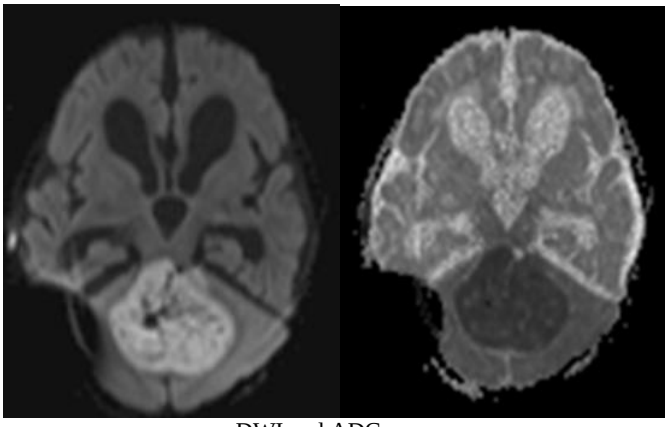
56 years male presents with severe headache, giddiness and vomiting since 3 months.
MRI shows an ill-defined intra axial enhancing mass T1 hypointense (not shown here) T2 hyperintense lesion with multiple blooming on gradient images with cystic lesions within seen in the right frontal lobe. The enhancing solid portion of the lesion shows restriction on DW images (mean ADC OF 0.444 $\times 10^{-3}$ mm^2 /s).
Biopsy Report: Glioblastoma multiforme.



T1 and T1 Contrast



T2 and FLAIR

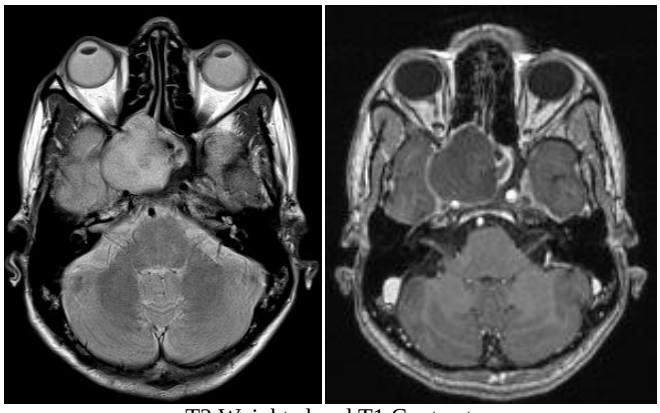


DWI and ADC map

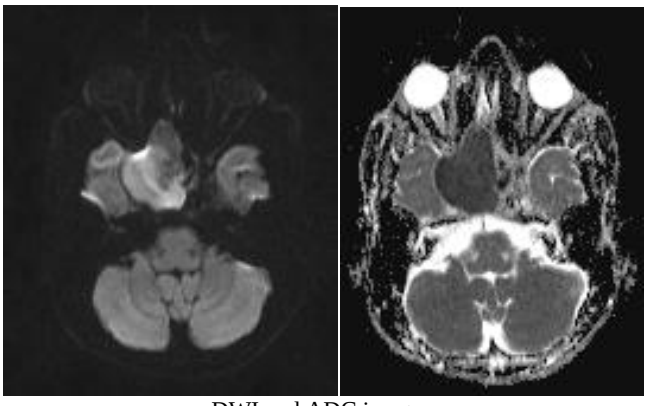
Figure 3: T1, T1 Contrast, T2 Weighted, FLAIR,DWI and ADC mapping

7 years aged male child presents with history of increase in size of head since 6 months. Also c/o blurring of vision, weakness of upper and lower limbs, unable to walk with high stepping gait with one episode seizure. MRI shows a large well defined T1 hypointense and T2/FLAIR iso to hyperintense, heterogeneously enhancing lesion in the fourth ventricle showing restriction on DWI (mean ADC OF 0.511×10^{-3} mm^2 /s).

Biopsy Report: Medulloblastoma- WHO grade-IV.



T2 Weighted and T1 Contrast

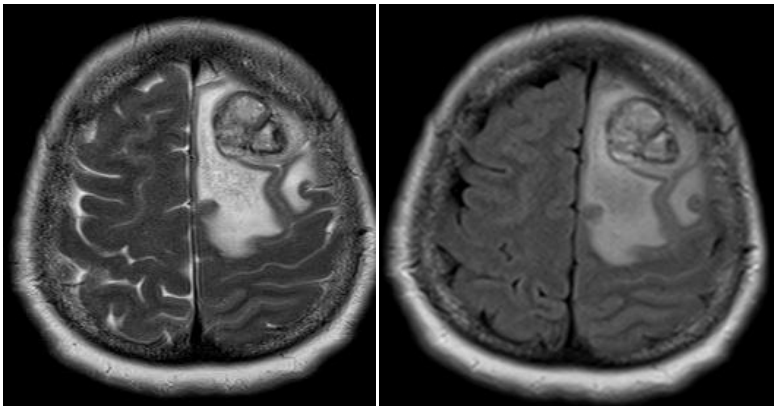


DWI and ADC images

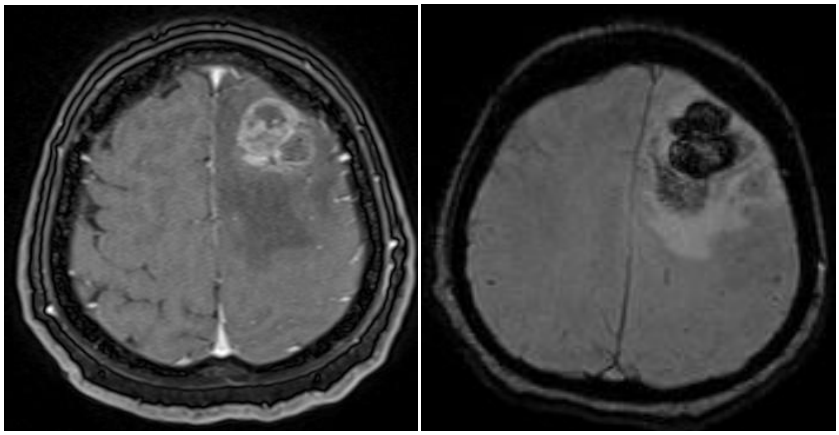
Figure 4: T1 Contrast, T2 Weighted, DWI and ADC mapping

32 years male presents with severe headache and vomiting since 3 months.

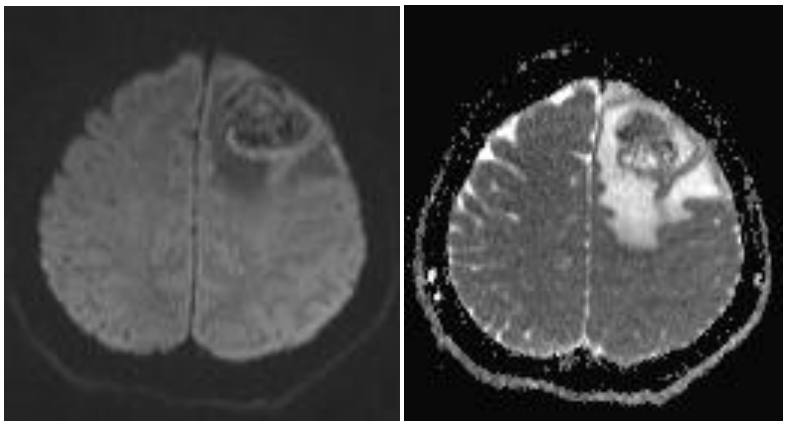
MRI shows a well-defined peripherally enhancing T2 heterogeneous signal intense lesion in the right sphenoid sinus region causing compression of right optic nerve at the apex and shows restriction on DW images (mean ADC OF 0.444×10^{-3} mm^2 /s)- Suggestive of Abscess.



T2 Weighted and FLAIR



T1 Contrast and SW Images



DWI and ADC images

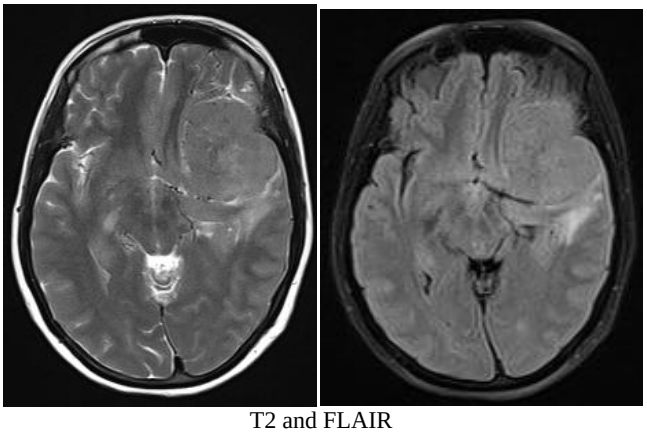
Figure 5: T1 Contrast, SWI, T2 Weighted, FLAIR, DWI and ADC mapping

49 Years female with c/o headache since 7 days sudden in onset severe in intensity, more in the left frontal region which relieved on taking medication, h/o weakness in right upper limb, difficulty in combing hair, mixing food.

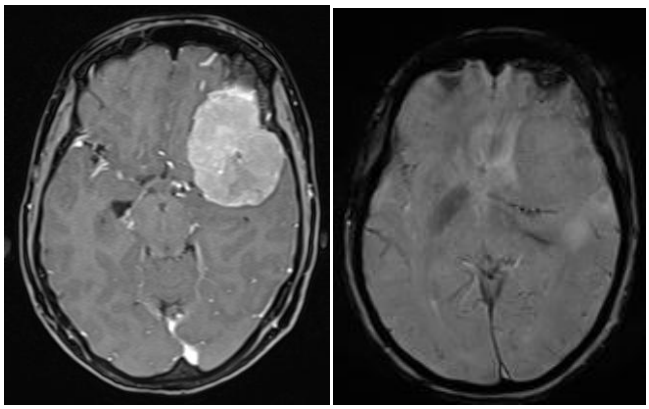
A fairly-defined intra axial enhancing lesion with multiple central hyperintensities on T2 weighted images and surrounding peritumoral edema in the left high frontal lobe showing diffusion restriction in the peripheral enhancing solid portion of the lesion on DW images (mean ADC: 0.81×10^{-3} mm^2 /s).

HPE Report: Section studied showed features of metastatic papillary adeno carcinoma.

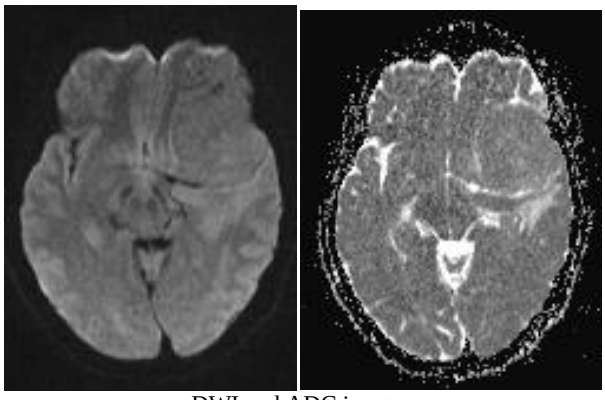
Diagnosis: Left frontal metastatic papillary adeno carcinoma.



T2 and FLAIR



T1 contrast and SW images



DWI and ADC images

Figure 6: T1 Contrast, SWI, T2 Weighted, FLAIR, DWI and ADC mapping

48 years female presented with headache more on left side with vomiting since 20 days. She had 2 episodes of seizures GTCS in past 15 days controlled with medications.

MRI shows a fairly well defined homogenously enhancing dural based lesion Diagnosis: Left sphenoid wing meningioma.

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involving the greater wing of left sphenoid causing mass effect and midline shift, extra axial mass lesion – s/o Meningioma
(Mean ADC: 0.84×10^{-3} mm^2 /s).

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