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# The Role of Diffusion-weighted Imaging in Patients with Brain Tumors

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## Introduction

Diffusion-weighted imaging is an MR imaging technique in which contrast within the image is based on microscopic motion of water. It was first described in 1965 by two physical chemists, Stejskal and Tanner. Diffusion-weighted images are obtained by adding a series of two sequential gradient pulses to a 90-180-degree spin-echo sequence. The first gradient pulse is applied between the 90 and the 180-degree pulse. Motion after this pulse causes molecules to acquire phase shifts of their transverse magnetization. Both the 180-degree and the second gradient pulse rephase stationary spins. Phase shifts acquired in mobile molecules lead to failure of such molecules to rephase completely, resulting in substantial signal loss.

A value known as apparent diffusion coefficient (ADC) is determined by diffusion weighting of the imaging sequence. This value is dependent on a number of variables including time, orientation of the imaging plane, the tissue being imaged, and the energy state of the imaged tissue. Signal intensity on a gray scale is directly related to ADC values on DWI. Brain tissue with low ADC values appears relatively hypointense, whereas regions with higher ADC values appear hyper intense.

Diffusion weighted imaging is a technique that assesses local environment at the cellular level to determine changes in the random movement of water protons. Restricted diffusion appears as an area of increased signal on DWI and reduced signal on ADC maps. The amount of diffusion weighting of a DW image depends on the magnitude of the applied gradients, how long they are switched on, and the time between the two lobes.

Whereas DWI is most often used to identify acute arterial ischemia, other processes that interfere with or restrict the movement of water can cause notable changes on DWI, including neoplastic lesions, encephalitis, pyogenic abscesses and occasionally Demyelinating disease.

DWI images aid in the diagnosis of various intracranial lesions and by comparing with the ADC and FLAIR images it will also be possible to characterise these lesions. DWI also helps to interpret the age of a lesion as in infarct and haemorrhage and also predict the grade of certain tumours.

## Aims and Objectives

1. To describe the usefulness of Diffusion Weighted MRI in imaging various intracranial lesions.
2. To discuss the imaging features in DWI and ADC of various intracranial lesion.

3. To characterise the lesions by comparing DWI features with ADC, T1WI, T2WI and FLAIR characteristics.

**Materials and Methods**

This study is descriptive study based on data collected from January 2016 to August 2016 in the Department of Radiodiagnosis, Sri Manakula Vinayagar Medical College and Hospital, Puducherry.

**Source of Data**

The source of data for this study is patients referred to the Department of Radiodiagnosis, Sri Manakula Vinayagar Medical College and Hospital, Puducherry, for MRI brain with diffusion weighted imaging. This consists of a study of 30 patients with intracranial tumors detected on imaging.

**Inclusion Criteria**

The criteria for inclusion of the patients in the study included those patients who were clinically referred for diffusion weighted MRI of the brain and were detected to haveintra/extra axial tumors.

**Exclusion criteria**

1. Vascular malformations such as AVM, Cavernous angiomas,etc.
2. Congenital malformations of the central nervous system.
3. Demyelination
4. Metabolic or toxic insults to the brain
5. Degenerative disorders
6. Contraindications for MRI: claustro-phobia, cochlear implant, etc.

**Data Acquisition**

Patients referred for diffusion weighted MRI of the brain, underwent the examination after contraindications for MRI were excluded and consent was taken.

All the MRI scans in this study were performed using 1.5 T MRI scanner (Philips)

**Data Analysis**

The present study was carried out to describe imaging characteristics of intracranial tumors on DWI and to compare them with ADC and T2 FLAIR images.

Findings in the patients studied were tabulated using Microsoft Excel.

All statistical analyses were conducted using the SPSS statistical package (version 16.0).

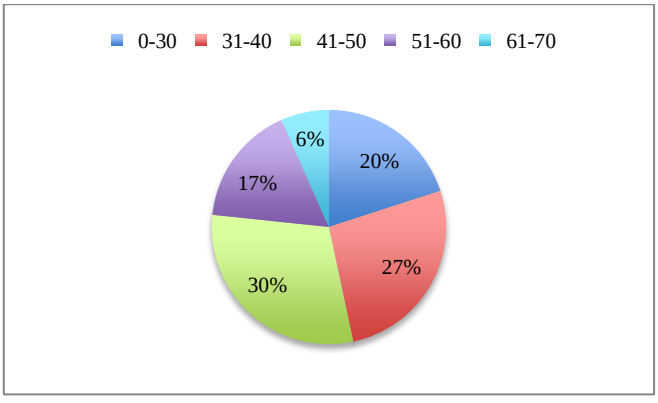
30 cases of intracranial tumors were included in the study. The observations of these 30 patients were compiled and analyzed.

**Table 1.1:** Distribution of Age

| | Frequency | Percent |
|---|---|---|
| **Up to 30** | 6 | 20% |
| **31 – 40** | 8 | 27% |
| **41 – 50** | 9 | 30% |
| **51 – 60** | 5 | 17% |
| **61 – 70** | 2 | 6% |
| **Total** | 30 | 100% |

The age of the patients with intra cranial lesions studied ranged from 2 years to 70 years with a mean age of 41.3 years. More number of patients belongs the age group 41-50 years (30.0%) followed by the groups 31-40 years (27.0%) and 0-30 years (20.0%). About 17.0% of the patients belong to age group 51-60 years and About 6.0% of the patients belong to age group 61-70

**Figure 1:** Distribution of Age



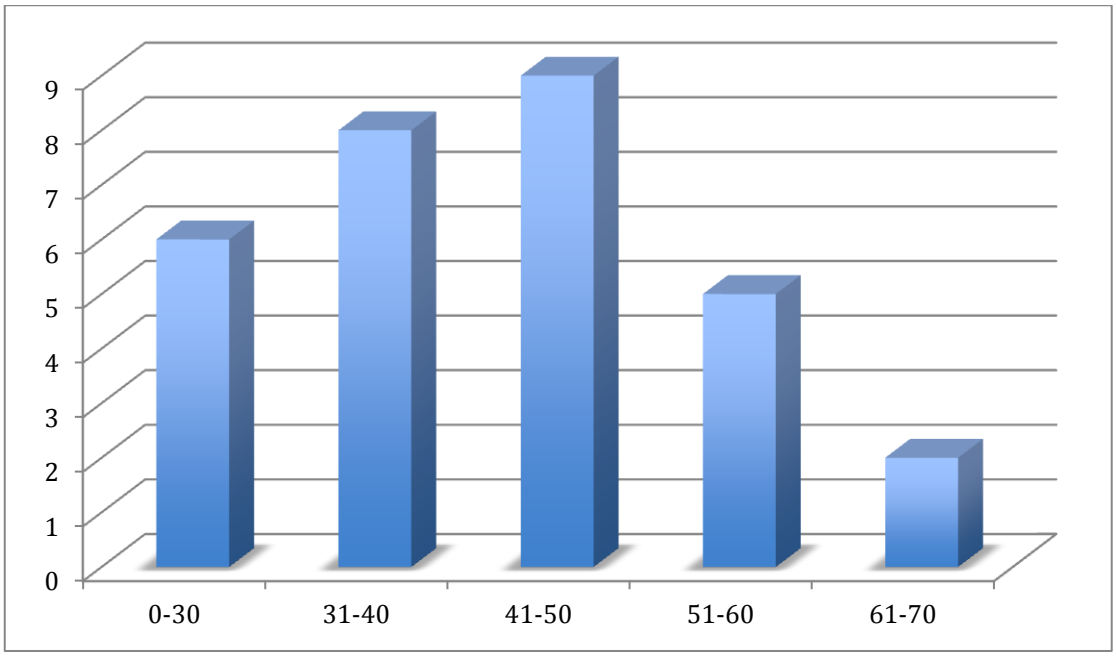



**Table 1:** Distribution of Diagnosis with Age

| Diagnosis | Age Group | | | | | Total |
|---|---|---|---|---|---|---|
| | Up to 30 | 31 - 40 | 41 - 50 | 51 - 60 | 61 - 70 | |
| **Arachnoid Cyst** | 2 | 1 | 2 | 0 | 0 | 5 |
| **Epidermoid Cyst** | 2 | 2 | 0 | 0 | 0 | 4 |
| **GBM** | 0 | 0 | 1 | 2 | 0 | 3 |
| **Intermediate Grade Glioma** | 0 | 1 | 1 | 0 | 0 | 2 |
| **Low Grade Glioma** | 0 | 1 | 2 | 2 | 0 | 5 |
| **Meningioma** | 0 | 2 | 2 | 1 | 2 | 7 |
| **Pilocytic Astrocytoma** | 2 | 0 | 0 | 0 | 0 | 2 |
| **Schwannoma** | 0 | 1 | 1 | 0 | 0 | 2 |
| **Total** | 6 | 8 | 9 | 5 | 2 | 30 |

**Table 2:** Distribution of Sex

| | Frequency | Percent |
|---|---|---|
| **Male** | 22 | 73.0% |
| **Female** | 8 | 27.0% |
| **Total** | 30 | 100.0% |

Of the 30 patients studied, 73.0% were males and 27% were females.

**Figure 2:** Distribution of Sex

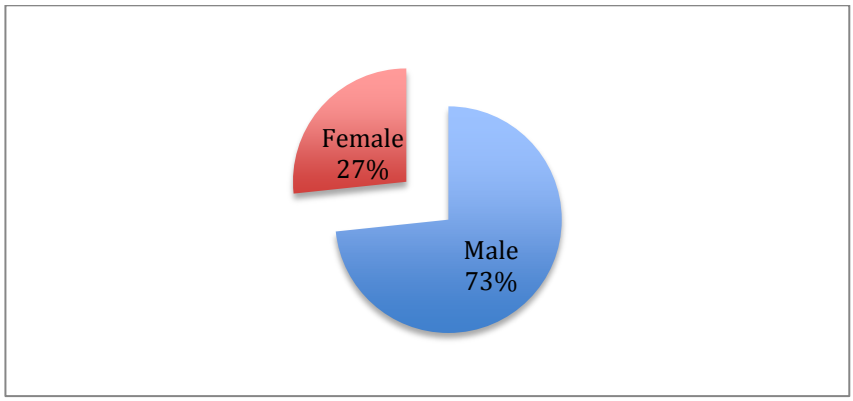


**Table 4:** Distribution of DWI

| | Frequency | Percent |
|---|---|---|
| ISO | 15 | 15.0% |
| HYPO | 9 | 9.0% |
| HYPER | 76 | 76.0% |
| Total | 100 | 100.0% |

**Figure 4:** Distribution of DWI

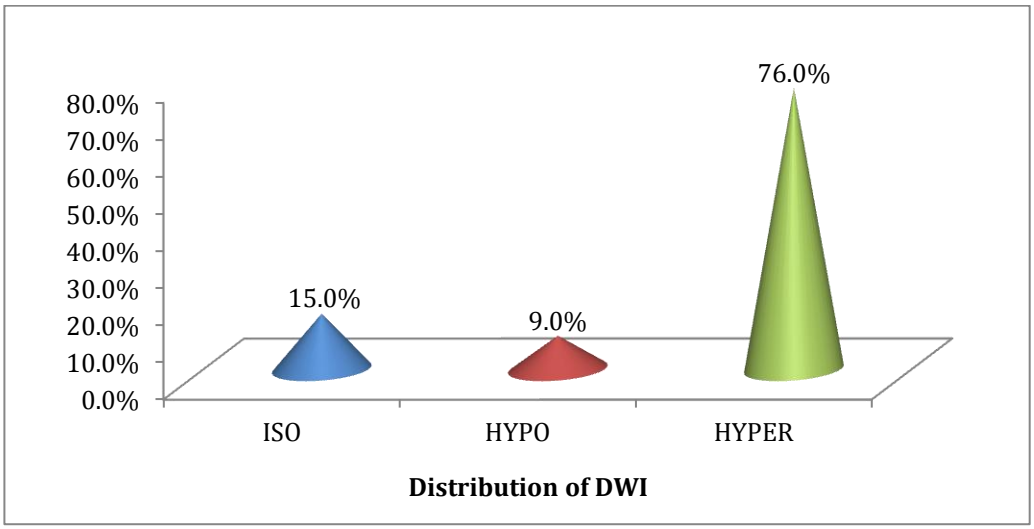



**Table 5:** Distribution of ADC

| | Frequency | Percent |
|---|---|---|
| ISO | 6 | 6.0% |
| HYPO | 49 | 49.0% |
| HYPER | 45 | 45.0% |
| Total | 100 | 100.0% |

**Figure 5:** Distribution of ADC

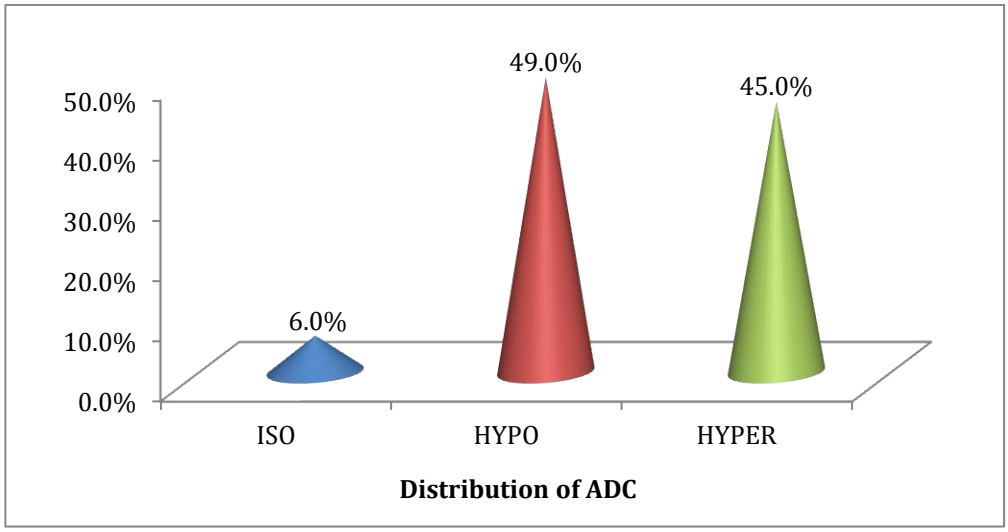
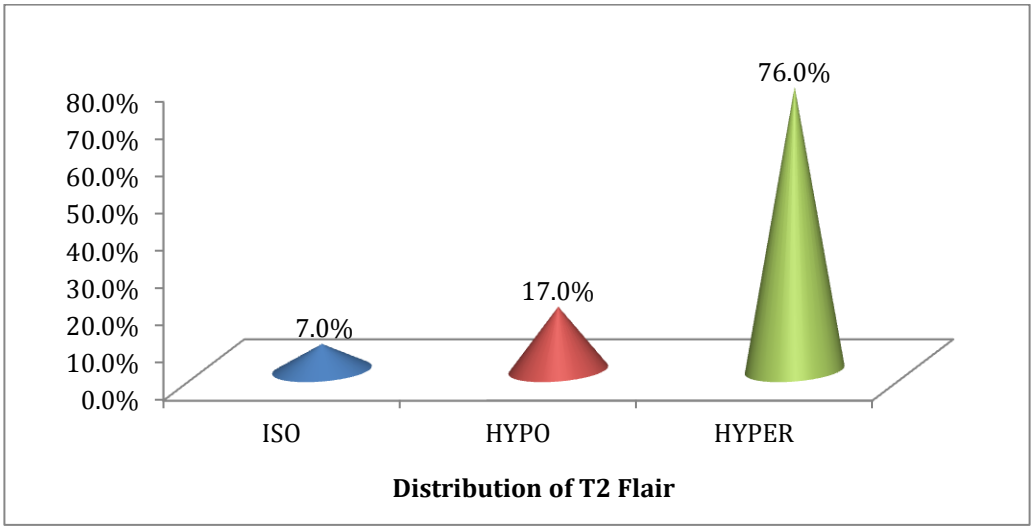



**Table 6:** Distribution of T2 Flair

| | Frequency | Percent |
|---|---|---|
| ISO | 7 | 7.0% |
| HYPO | 17 | 17.0% |
| HYPER | 76 | 76.0% |
| Total | 100 | 100.0% |

**Figure 6:** Distribution of T2 Flair



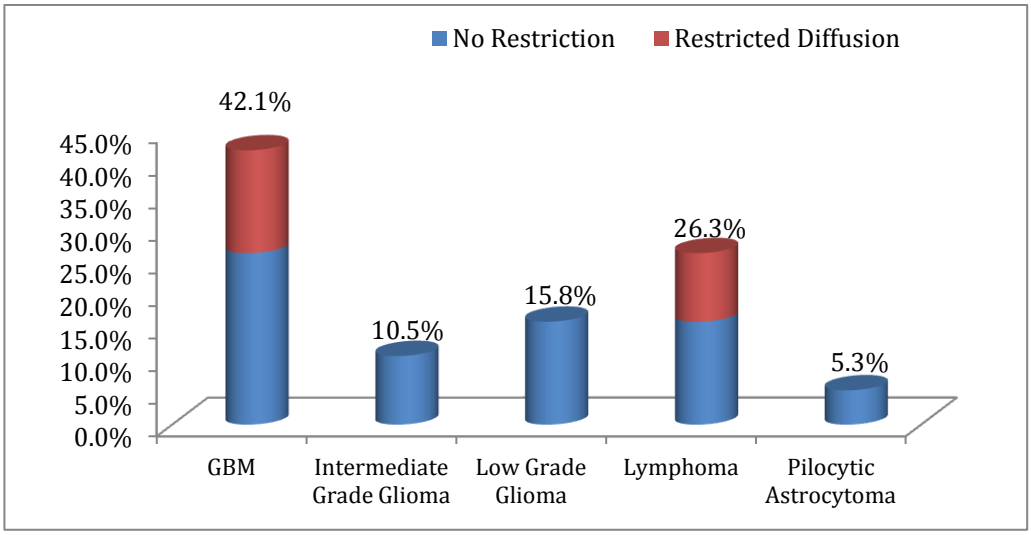

**Tumours**

**Table 8:** Distribution of Intra Axial Tumors

| | Frequency | Percent |
|---|---|---|
| GBM | 8 | 42.1% |
| Intermediate Grade Glioma | 2 | 10.5% |
| Low Grade Glioma | 3 | 15.8% |
| Lymphoma | 5 | 26.3% |
| Pilocytic Astrocytoma | 1 | 5.3% |
| Total | 19 | 100.0% |

There were 19 cases of intra axial tumors in this study. The age of the patients ranged from 12 to 65 years with a mean age of 49.47 ± 11.34 years. There were 14 (73.7%) males and 5 (26.3%) females among these cases. This included 8 cases of glioblastoma multiforme, 2 cases intermediate grade gliomas, 3 cases of low grade gliomas, 5 cases of lymphomas and 1 pilocytic astrocytoma. Of the 19 intra axial tumors, 5 cases (26.3%) showed true diffusion restriction. About 37.5% of GBM (3 cases) and 40% (2 cases) of lymphomas showed true restriction of diffusion.

**Figure 8:** Distribution of Intra Axial Tumors




T2 shine through was noted in 12 cases (63.1%). This included all 2 cases of intermediate grade glioma, 5 cases (62.5%) of GBM, 2 cases (66.7%) of low gradegliomas and 3 cases (60%) of lymphoma.

T2 washout was seen in 1 case of pilocyticastrocytoma and 1 case (33.3%) of low grade glioma.

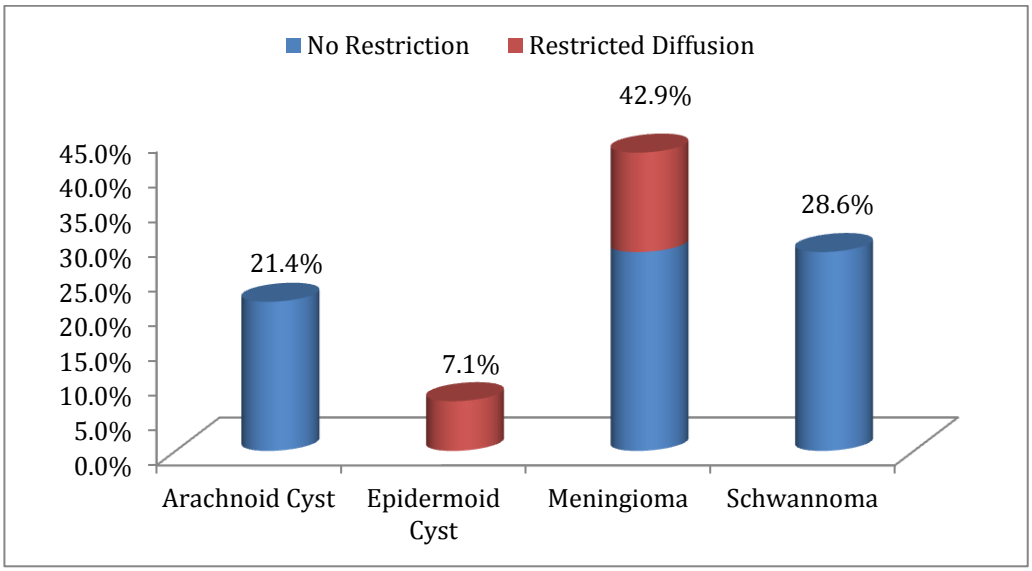
**Table 9:** Distribution of Extra Axial Tumors

| | Frequency | Percent |
|---|---|---|
| Arachnoid Cyst | 3 | 21.4% |
| Epidermoid Cyst | 1 | 7.1% |
| Meningioma | 6 | 42.9% |
| Schwannoma | 4 | 28.6% |
| Total | 14 | 100.0% |

There were 14 cases of extra axial tumors in this study. The age of the patients ranged from 31 to 69 years with a mean age of 48.64 ± 11.94 years. There were 10 (71.4%) males and 4 (28.6%) females among these cases. This included 3 cases of arachnoid cyst, 1 case of epidermoid cyst, 6 cases of meningioma, and 4 cases of schwannoma. Of the 14 extra axial tumors, 3 cases (21.4%) showed true diffusion restriction. The only one case of epidermoid cyst and 2 cases (33%) of meningioma showed true restriction of diffusion.

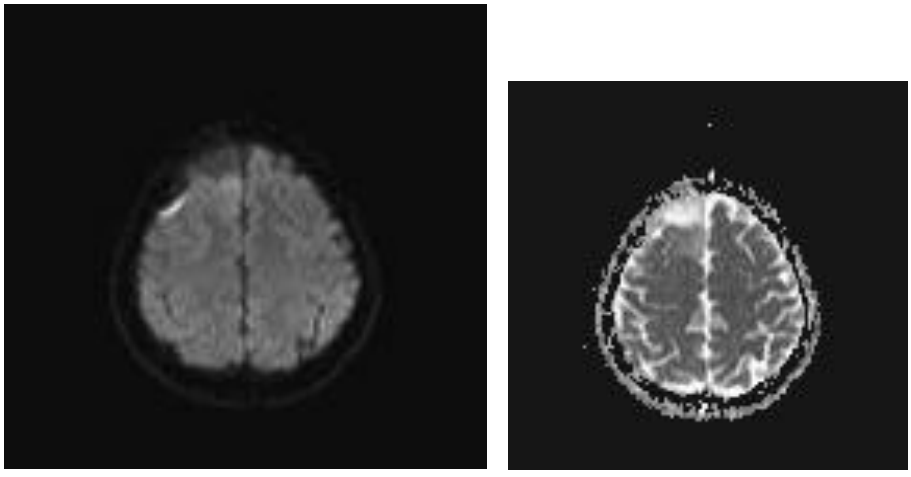
In one case of meningioma, T2 shine through was noted. In 4 (66.7%) cases of meningiomas, T2 FLAIR showed iso to hypointense signal probably due to high cellularity and presence of calcification. 1 case (25%) of schwannoma showed T2 washout.

**Figure 9:** Distribution of Extra Axial Tumors

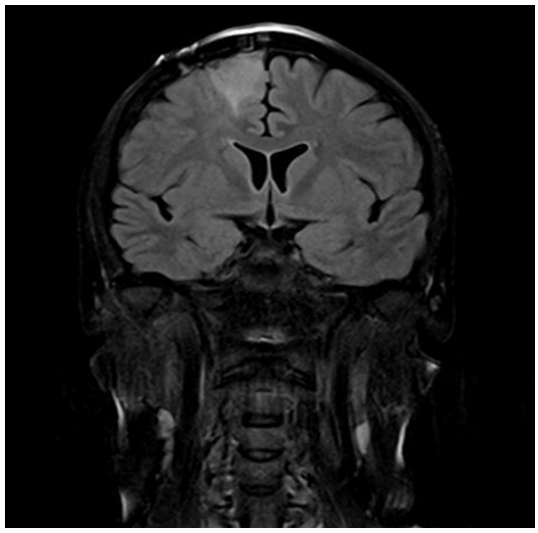



**Gliomas**

**Low Grade Glioma**



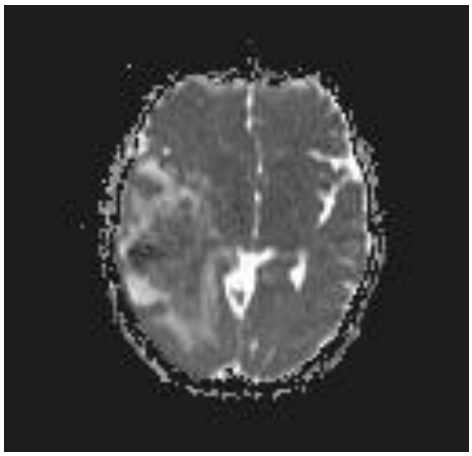
a) DWI b) ADC



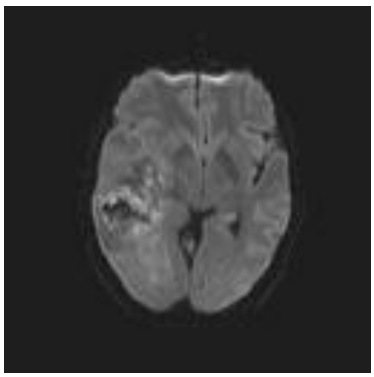
c) FLAIR

**Figure 6**: Low grade astrocytoma – FLAIR hyperintense lesion noted in the right high frontal cortex and adjacent white matter which shows no restriction of diffusion (hypointense in DWI and hyperintense in ADC). Post contrast study (not shown) shows no enhancement.

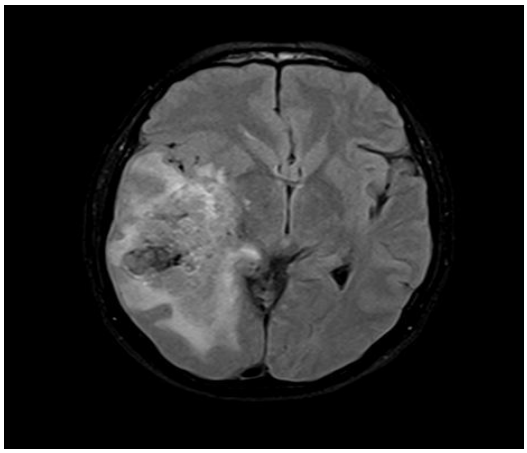
**High Grade Glioma**



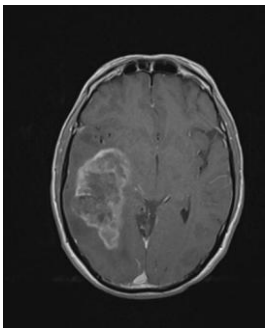
a) ADC



b) DWI



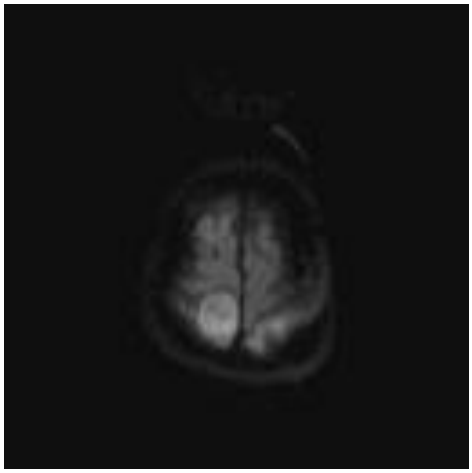
c) FLAIR



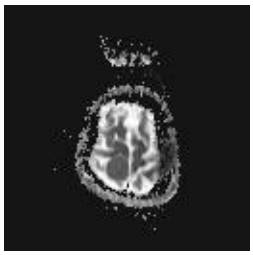
d) T1 post contrast

**Figure 7**: Altered signal which is predominantly hypo to isointense in FLAIR (c) noted involving the right temporal lobe extending into occipital lobe with associated edema (hyperintense on FLAIR). Patchy areas of DWI hyperintensity and ADC hypointensity noted. Post contrast study shows patchy enhancement of the lesion – High grade glioma - GBM

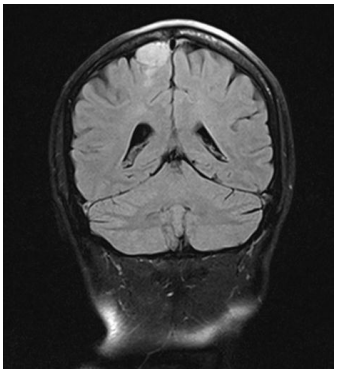
**Meningioma**



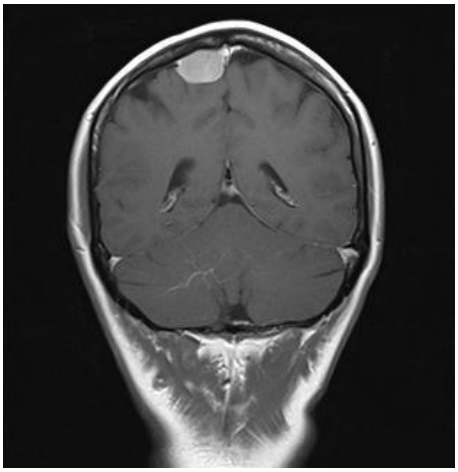
a) DWI



b)ADC



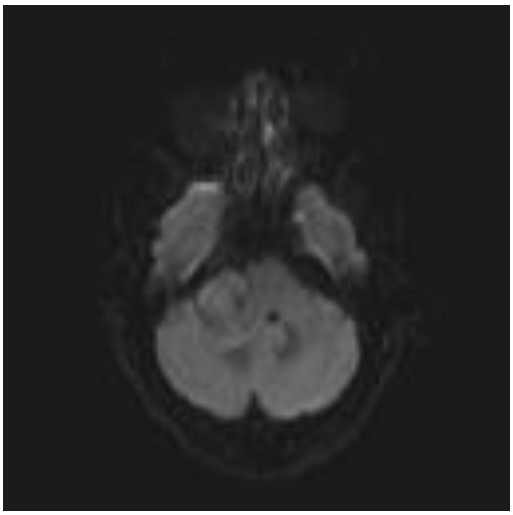
c)FLAIR



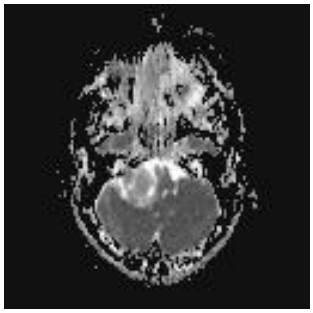
d)T1 post contrast

**Figure 11**: Right parasagittal convexity meningioma- Well defined, well marginated, FLAIR hyperintense(c), brightly enhancing extraaxial dural based lesion noted in the parasagittal aspect of right parietal region. Enhancing dural tail noted(d). However no sinus invasion or obstruction. The lesion shows restriction of diffusion. Ie. Hyperintense on DWI and hypointense on ADC (a,b)

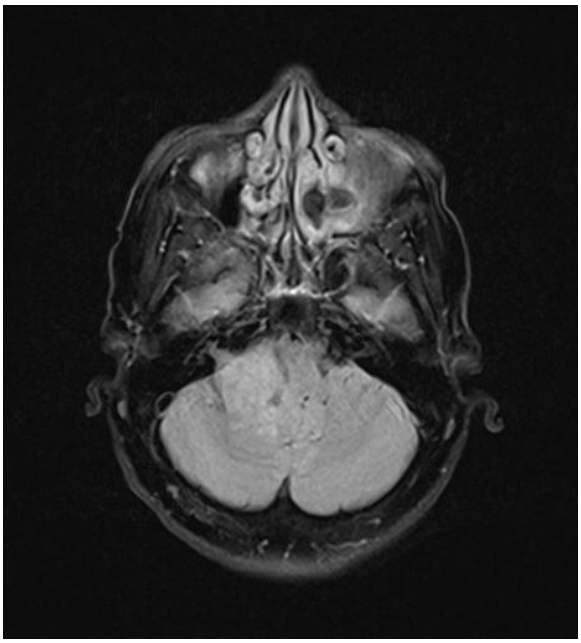
**Acoustic Schwanomma**



a)DWI



b)ADC



c)FLAIR

**Figure 12**: Right acoustic schwanomma - Well defined, well marginated extra axial lesion noted involving the right CP angle with intracanalicular component in the right IAM causing widening of the same. The lesion causes significant compression of the right middle cerebellar puduncle. The medulla and the pons causing compression and splaying of the structures to the left, narrowing of the 4th ventricle .The lesion shows no significant restriction of diffusion.

**Discussion**

**Diffusion weighted imaging (DWI)** is a form of MR imaging based upon measuring the random Brownian motion of water molecules within a voxel of tissue. The relationship between histology and diffusion is complex, however generally densely cellular tissues or those with cellular swelling exhibit lower diffusion coefficients, and thus diffusion is particularly useful in tumour characterisation.

In this study 30 patients with intracranial lesions detected on MRI of the brain wereincluded. It was found that DW MRI provides added information in the evaluation of intracranial lesions including, intra-axial lesions and extra-axial lesions in conjunction with conventional MRI.

**Tumors**

**Intra axial tumors**

MR imaging is the most sensitive method of detecting tumors of the brain. It is howevernot specific enough to determine the histological nature of most tumors. DWI candifferentiate between tumor and infection and can provide information about thecellularity of tumors thereby helping in characterization and grading of tumors. Cruz CH et al, showed that highly cellular tumors such as high grade gliomas andlymphomas can have low ADC values and show restricted diffusion.

The findings of this study were similar. In this study, 37.5% of GBM and 40% of lymphomas showed true restriction of diffusion. None of the low gradegliomas or anaplastic astrocytomas showed restricted diffusion.

**Extra axial tumors**

Diffusion weighted MR plays a key role in differentiating arachnoid from epidermoid cysts. Schaefer et al showed that conventional MR cannot be reliably used todifferentiate these two lesions as both have CSF like signal intensity on conventional MR sequences. However on DWI epidermoid cyst shows restricted diffusion while arachnoid cyst shows CSF like intensity. This was also demonstrated in a study by Cruz et al , in

which epidermoid cysts had ADC values similar to brain parenchyma while arachnoid cysts had ADC values similar to CSF.

In this study all 3 cases of arachnoid cysts had signal similar to CSF on DWI and ADC images. The single case of epidermoid cyst noted in this study had restricted diffusion. Tadeusz et al and Cruz et al concluded that most meningiomas are isointense on DWI. Only few may show restricted diffusion depending on their cellularity. In their study 23% of meningiomas showed restricted diffusion. This study had similar results with 33% of meningiomas showing true diffusion restriction.

Schwannomas show high signal on ADC images with no restricted diffusion reflecting lack of high cellularity.

**Conclusion**

Diffusion weighted MRI is a valuable technique that provides unique information about the physiological state of brain tissue. The current study comprised 50 patients evaluated in Sri Manakula Vinayagar Medical College and Hospital, Puducherry who underwent DW MRI of the brain when they were referred for suspected intracranial lesions. All the MRI scans in this study were performed using 1.5T MRI scanner (Philips).

By using a combination of various MR sequences coupled with DWI and ADC images a valuable diagnosis may be provided to the clinicians. In this study the signal characteristics of various lesions on DWI, ADC, T2 FLAIR were studied.

DWI can provide valuable information about tumor cellularity and help in the characterization of tumors and grading of tumors. The solid portion of high grade tumors may show restricted diffusion. True restriction was not observed in low gradegliomas. Pilocytic astrocytoma did not show true restriction. Lymphomas may also show restricted diffusion due to their high cellularity. In the evaluation of extra axial cystic lesions, DWI plays an important role. While conventional MR sequences may be inconclusive in the differentiation of epidermoid cyst from arachnoid cyst, DWI shows restricted diffusion in the former and helps distinguishing the two. Among extra axial tumors, restricted diffusion has been noted in meningiomas. There is no restriction of diffusion in schwannomas.

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