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Evaluation and Characterisation of Brain Tumors by Perfusion Weighted MRI

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ABSTRACT

Aims and Objectives:

Perfusion MRI demonstrate the functional behavior of brain tumors and helps to differentiate them into low and high grade tumors using values of, rCBV, rCBF and MTT which further help in treatment planning. The study is helpful in predicting the outcome of the treatment and to differentiate tumor recurrence from radiation necrosis.

Materials and Methods:

A Prospective study of 51 patients with suspecting brain tumors clinically were examined on GE 1.5T SIGNA-MR scanner. Conventional sequences, Perfusion (Dynamic Susceptibility Contrast) and contrast studies were done.

Results:

Among 51 patients, the most common type tumor diagnosed was glioma (44.5%) including in all age groups and gender. 2nd most common tumor was meningiomas (20.4%). 57.5 % of patients were diagnosed to have low grade tumor and 42.5% of patients were diagnosed to have high grade tumors.

Conclusion:

Accuracy of grading of tumors done based on routine MR imaging and perfusion imaging sequences was found to be significantly more Routine use of these values and further research is needed in order to improvise the accuracy of the study.

Keywords: Magnetic resonance imaging, Brain tumors, Perfusion weighted imaging

INTRODUCTION

T*umor* is equated with neoplasm, which means "new growth." All tumors have two basic components: (1) neoplastic cells that constitute the tumor *parenchyma* and (2) reactive stroma made up of connective tissue, blood vessels, and variable numbers of cells of the adaptive and innate immune system.[1] Brain tumor is a mass or growth of abnormal cells in the brain and its coverings (meninges).[2]

Magnetic resonance imaging is the method of choice for the imaging of CNS diseases. Computed tomography is an alternative in case of emergency or MRI contraindications.10 The role of the most commonly used advanced MR imaging techniques—perfusion imaging, diffusion-weighted imaging, and MR spectroscopy—in the diagnosis and classification of the most common brain tumors in adults is explored. These lesions include primary neoplasms (high- and low-grade), secondary (metastatic) neoplasms, lymphomas and cysts. [1]

Advanced MRI sequences like dynamic contrast imaging (perfusion weighted images), diffusion weighted image and MRS are potentially be helpful in distinguishing treatment effect from true treatment failure. [4], [5]

MATERIALS AND METHODS

This is a prospective study of 51 patients with suspected brain tumors referred to department of Radio diagnosis, KIMS Bangalore. The study was conducted over an 18 months of period. The MRI brain scan was performed on G.E 1.5 Tesla scanners.

MRI protocol: All subjects underwent "standard brain tumor protocol". Standard protocol includes conventional T1 weighted sagittal, T2 weighted axial, FLAIR axial and (susceptibility weighted imaging) SWI/GRE sequence. Contrast examination done using T1+FS sequence. Advanced MRI sequences include DWI/ADC, MR Spectroscopy and PWI sequences. MRI imaging parameters are given in Table 1.

RESULTS

The study consisted of a total of 51 patients including both paediatric, young and adult patients with no age barrier. Out of a total of 51 patients, 8 were paediatric, young patients and rest 43 fell under the category of adults. Most of the adult population belonged to the fourth and fifth decade. The study showed a slight female preponderance. Among the 51 patients, 10 were previously diagnosed or previously operated for brain tumors. Such patients were assessed for any recurrence or residual lesions. Among the 51 patients, most common type tumor diagnosed was glioma accounting for about 44.5% including in all age groups and gender. 2nd most common tumor was meningiomas accounting for about 20.4% followed by nerve sheath, neoplastic cysts and metastasis accounting for about 7.8%. Embryonal, glioneuronal and others tumors accounted for 4% approximately (Table 2). Among the 51 patients, 29 patients were diagnosed to have low grade tumor and 22 patients were diagnosed to have high grade tumors accounting for about 57.5 % and 42.5% based on MR imaging features on routine sequences including perfusion weighted imaging sequences(Table 3). While grading the tumor various characteristics like tumor necrosis, haemorrhage, calcification, infiltration and advanced parameters like rCBV, rCBF and MTT values are considered.

DISCUSSION

Magnetic resonance imaging is the method of choice for the imaging of brain tumors. MRI plays an important role in the diagnosis, treatment planning, and post therapy assessment of brain tumors.

Perfusion-Weighted Imaging (PWI)

Several MR perfusion techniques are currently employed: dynamic susceptibility contrast (DSC), dynamic contrast enhanced (DCE), and arterial spin labeling (ASL). Of these, DSC perfusion is the most studied and widely applied, while ASL, does not require intravenous contrast, has been the subject of increasing investigation and clinical implementation.[6], [7], [8]

DSC is based on the detection of susceptibility induced signal loss on T2*-weighted sequences after the administration of an intravenous gadolinium contrast agent. A signal intensity time curve is generated from which relative cerebral blood volume (rCBV) and other perfusion metrics are derived. rCBV is elevated in tumor, where it is seen as a marker of angiogenesis, and has been shown to distinguish tumor from non-neoplastic etiologies with lower rCBV such as demyelinating lesions. A signal intensity time curve that does not return to baseline is seen with leaky capillaries and can suggest metastasis, meningioma, or choroid plexus tumor.[53] rCBV has been positively correlated to glioma grade (Fig. 1, 2), although some lower grade gliomas such as oligodendrogliomas may have elevated rCBV.[9], [10] rCBV has been noted to be increased in infiltrative edema of gliomas compared to acellular vasogenic edema surrounding metastases, a characteristic which may be used to better target biopsy.56 rCBV may also predict areas of progression in glioma prior to changes on contrast-enhanced MRI as well as survival.[6], [11]

Using dynamic susceptibility contrast, it is relatively straightforward to calculate a relative CBV (rCBV) from the area under the measured signal–time curve. Because it is quite insensitive to the actual shape of the AIF, this quantity is considered to be a quite robust measure of rCBV as long as the relation between tissue concentration and signal intensity is

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the same throughout the brain.[12], [13], [14] rCBV values are frequently normalized to healthy-appearing white matter to facilitate comparison between patients. Cerebral blood flow is much more difficult to obtain since for intravascular tracers the transit time is very short and thus the influence of CBF on the tissue concentration–time curve is rather subtle. Therefore, the bolus arrival time (BAT), the time to peak (TTP), and the relative mean transit time (rMTT), i.e., the full width at half maximum of the signal–time curve, are frequently used as surrogate markers of perfusion.[12], [15] DSC-MRI is by far the most frequently used perfusion imaging method.

Dynamic contrast-enhanced (DCE) perfusion imaging relies on the acquisition of a time series of T1 weighted images during bolus application and allows quantification of vessel permeability, which is merely a confounding factor in DSC- based perfusion imaging. Generally, DCE-MRI requires the acquisition of a time series of T1 weighted images over several minutes to observe the wash-in and washout of contrast agent in extravascular extracellular space Qualitative or semi quantitative measurements of leakage-related parameters are relatively easy to perform. The slope of the wash-in and washout portions of the time course can be evaluated within the regions of interest, allowing the distinction of tumor (fast rise) and radiation necrosis (slow rise).[16] Also, semi quantitative parametric maps of the wash-in and washout slopes, maximal enhancement, and arrival time can easily be created. Integration of the initial area under the DCE tissue concentration curve (initial AUC) yields a more quantitative parameter [17], [18], [19] without the need for a sophisticated model. [12]

This method describes the tissue as consisting of an intravascular space (plasma volume vp) and an extravascular extracellular space (EES, volume ve) .The distribution of the contrast agent is characterized by arterial delivery and venous elimination rates ka and ke as well as distribution and redistribution rate constants k12 and k21, which describe the diffusion into EES. Commonly measured parameters are the volume transfer constant Ktrans between blood plasma and EES Ktrans = E·CBF · (1- Hct) with extraction fraction E and haematocrit Hct), the EES volume fraction ve, and the rate constant between EES and blood plasma kep= Ktrans/ve. However, the interpretation of Ktrans depends on the physiological conditions: when the vessel permeability is much higher than blood flow (flow-limited condition), Ktrans corresponds to the blood plasma flow per unit volume of tissue; when blood flow is much higher than vessel permeability (permeability-limited condition), Ktrans corresponds to the permeability surface area product per unit volume of tissue.[12], [20]

The major drawback of DCE-MRI in comparison to DSC based perfusion imaging is the significantly reduced signal change, which results in rather low SNR in the calculated parameter maps. In practice, it is also much more demanding to achieve a reasonable spatial coverage and temporal resolution with T1 weighted imaging methods, and it is more difficult to choose an appropriate method from the large variety of different approaches. [12]

Arterial spin labelling is an alternative agglomeration of methods for measurement of cerebral blood flow which uses magnetically labelled water in blood vessels as endogenous diffusible tracer. The basic idea is to acquire two data sets, one with labelling of inflowing blood and one without. The difference signal is proportional to the delivered magnetization and hence to blood flow. Because labeled water acts as a freely diffusible tracer with accordingly prolonged tissue transit times, CBF derived from arterial spin labelling (ASL) is principally more robust than CBF derived from bolus tracking based on intravascular tracers. Detecting the grade preoperatively helps in deciding the prognosis of surgery, chemotherapy and radiotherapy. [12]

CONCLUSION

Analysis of epidemiological trends, symptomatology and characterization of brain tumors with routine and additional MRI sequence like PWI was done in our study.

Most common type of brain tumors among the study group was gliomas irrespective of age and gender, followed by meningiomas which were common after 4th decade of life. Rest of the tumors were below the 10% of the study group.

Accuracy of grading of tumors done based on routine MR imaging and perfusion imaging sequences was found to be significantly more (Sensitivity: 93.3 % and specificity:86. 5%).PWI parameters were also significantly helpful in detecting tumor recurrence

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and differentiating it from radiation necrosis and pseudoprogression

Tables and Figures

	3D T1w Pre[b]	Ax 2D FLAIR[j]	Ax 2D DWI	Contrast Injection [a]	Ax 2D T2w[h,j]	3D T1w Post[b]
Sequence	MPRAGE[e,f]	TSE[c]	SS-EPI[g]		TSE[c]	MPRAGE[e,f]
Plane	Sagittal/ Axial	Axial	Axial		Axial	Sagittal/ Axial
Mode	3D	2D	2D		2D	3D
TR [ms]	2100[m]	>6000	>5000		>2500	2100[m]
TE [ms]	Min	100-140	Min		80-120	Min
TI [ms]	1100[n]	2000-2500[k]				1100[n]
Flip Angle [Degrees]	10-15	90/≥160	90/180		90/≥160	10-15
Frequency	≥172	≥256	≥128		≥256	≥172
Phase	≥172	≥256	≥128		≥256	≥172
NEX	≥1	≥1	≥1		≥1	≥1
Frequency Direction	A/P	A/P	R/L		A/P	A/P
FOV	256mm	240mm	240mm		240mm	256mm
Slice Thickness	≤1.5mm	≤4mm[l]	≤4mm[l]		≤4mm[l]	≤1.5mm
Gap/Spacing	0	0	0		0	0
Diffusion Options[p]			b = 0, 500, 1000 s/mm² ≥3 directions			
Parallel Imaging	Up to 2x	Up to 2x	Up to 2x		Up to 2x	Up to 2x
Scan Time (Approx)	5-10 min [5:49 for 1mm isotropic]	4-8 min [3:22 for 2D FLAIR]	2-4 min [1:22 for 3 direction DWI and 3 b-values]		4-8 min [5:10 for dual echo]	5-10 min [5:49 for 1mm isotropic]

Table 1: MRI PROTOCOL BRAIN TUMOR IMAGING

TYPES OF TUMORS	*NO,*	*%*
GLIOMAS	23	44.5
MENINGEAL TUMORS	11	20.4
NERVE SHEATH TUMORS	4	7.8
EMBRYONAL NEOPLASMS	2	3.9
GLIONEURONAL TUMORS	2	3.9
METSTASIS	4	7.8
NEOPLASTIC CYSTS	4	7.8
OTHERS	2	3.9

TABLE 2: TYPES OF TUMORS

MRI GRADING	*No. of subjects*	*%*
LOW	29	57.5
HIGH	22	42.5
TOTAL	51	100.0

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TABLE 3: MRI GRADING BASED ON PWI WITH ROUTINE SEQUENCES

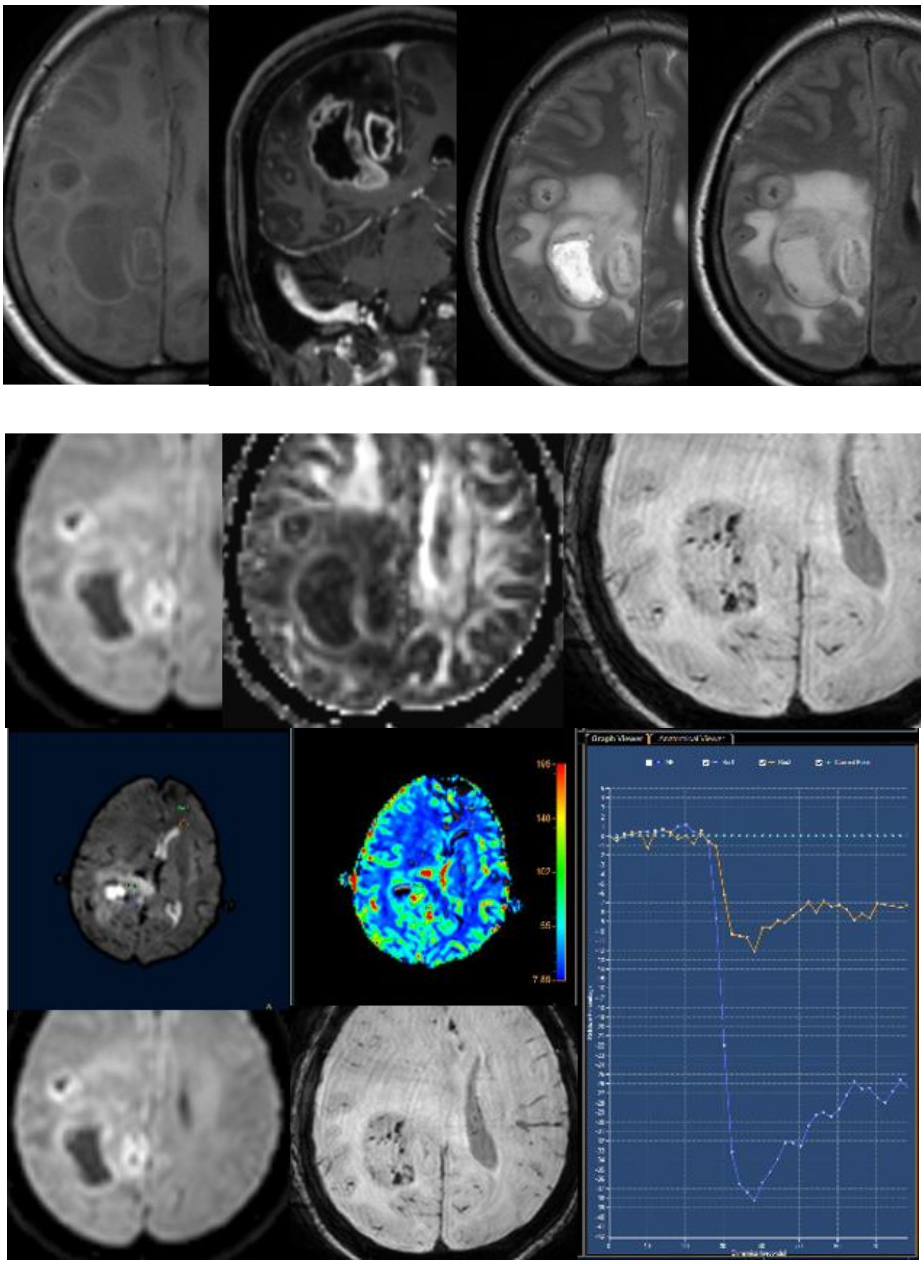

Fig 1: Ill-defined T1 hypo, T2 hyperintense solid cystic lesion in right parietal cortex and subcortical white matter with perilesional edema. The lesion shows patchy diffusion restriction, few areas of blooming within and heterogeneous enhancement on contrast study. On PWI there is increased rCBV value. Bx: Glioblastoma

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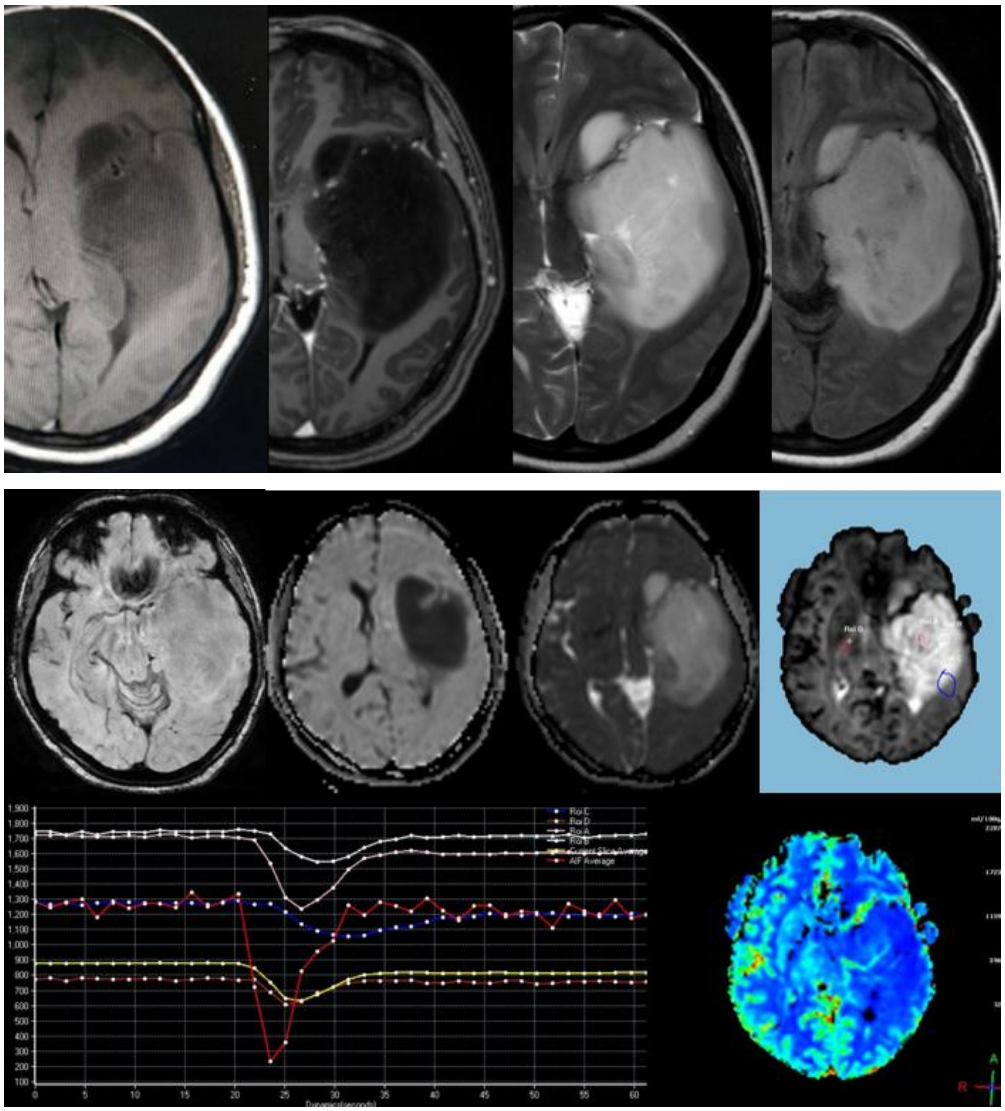

Fig 2: Well-defined T1 hypo and T2 hyperintense lesion noted in left fronto-temporal cortex and subcortical white matter. There is no evidence of diffusion restriction within the lesion. There is no evidence of elevated rCBV. Bx: Diffuse astrocytoma

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