Diagnostic role of magnetic resonance spectroscopy in intracranial space occupying lesions (IC-SOLs): a prospective analytical study

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Aims and objectives

The patients presenting with intracranial space occupying lesions were assessed with a detailed clinical history, conventional MRI and using Proton MR Spectroscopy. We attempted to characterise the lesions based on the biochemical information provided by MRS and assessed its usefulness as a complimentary tool to Magnetic Resonance Imaging.

Our objectives were:

1. To assess the accuracy of MR Spectroscopy in diagnosis of intracranial space occupying lesions (ICSOLs).
2. To assess the diagnostic accuracy of proton MR Spectroscopy in differentiation of benign and malignant lesions.
3. To assess the role of MR Spectroscopy in the grading of intracranial tumours.
4. To assess the role of MR Spectroscopy in diagnosing and differentiating inflammatory lesions.
5. To assess the diagnostic accuracy when MRI is combined with MR Spectroscopy in diagnosis and characterisation of brain lesions.
Methods and materials

The prospective analytical study was carried out at a centre in India between 2012 and 2013. Magnetic resonance studies were performed on a 1.5 Tesla whole body MR System with multinuclear spectroscopic capabilities using standard head coils (circularly polarized phased array head coil).

The subjects selected for the study were those referred with suspected intracranial space occupying lesions (ICSOLs). After eliciting a detailed clinical history (headache, seizures, vomiting, hemiparesis and dementia) and clinical examination, magnetic resonance imaging was performed.

INCLUSION CRITERIA

Patients with intracranial space occupying lesions on MRI.

EXCLUSION CRITERIA

- Trauma and cerebrovascular accidents - Hemorrhage or infarct.
- Aneurysms and vascular malformations.
- Mettalic implants, pace makers, fixators and claustrophobia.

Based on these criteria, fifty patients with ICSOLs detected on conventional MR Imaging were subjected to Magnetic Resonance Spectroscopy. As control for the spectroscopic studies the normal spectrum obtained from the corresponding contra-lateral or normal parts of the brain were taken.

PROCEDURE AND PARAMETERS:-

Initially, each patient was subjected to routine spin echo (SE) sequences -

1. T1 Weighted Images (TR/TE (repetition time/time to echo) - 500/9)
2. T2 Weighted Images (TR/TE - 4900/102.8)
3. Diffusion Weighted Images
4. Contrast enhanced T1 Weighted Images (if needed)

Off- line spectral post processing was carried out using semi automated software (1.5 Tesla MR equipment). Spectral heights of the metabolites Choline, Creatinine, N-acetyl aspartate, Lactate, Lipid, Myoinositol, Alanine, Glutmate-Glutamine and other amino acids were studied.
**MR Spectroscopy:**

Volume of interest from the lesion was selected on SE T2 weighted images or in heterogenous lesions, areas of solid enhancement were selected. For necrotic and cystic lesions spectrum from within the lesion was analysed separately. Multivoxel spectroscopy (Chemical shift imaging, CSI) (voxel 1-8 cm) was performed in these lesions. Corresponding contra-lateral areas were also analyzed for the metabolite ratios as control. SVS studies were performed with Point Resolved Spectroscopy (PRESS) sequence \{TR/TE/Ac (repetition time/time to echo/acquisitions) (1500/135&30/128}\}. CSI was performed using (1690/135&30/4) parameters. The SVS-SE-135 spectra were used for metabolite ratio calculations.

Prior to spectroscopic measurements, global shimming to adjust for static magnetic field inhomogeneity and local shimming \{measured as Full Width at Half Maximum (FWHM)\} for static and dynamic magnetic field inhomogeneities were carried out. The global shimming was optimized at 15-17 Hz, and FWHM between 5-7 Hz. Water suppression was carried out using a gaussian pulse. As far as possible, areas of oedema and adjoining calvarium were avoided to prevent signal contamination. Optimal FWHM and water suppression were achieved in most cases, however, the location and heterogeneous nature of the lesions prevented optimal shimming in some patients.

The area under the curve of a metabolite was considered as relative concentration \{integral values\} and was measured in terms of ratios. Measuring metabolite peak area ratios has the advantage of cancelling out the effects of general reduction in measured metabolite concentrations due to variations in cellular density. As reference standards, values of Cho/Cr > 1.5, NAA/Cr < 1.6 and Cho/NAA > 0.8 were taken as abnormal.

The metabolites and ratios assessed were:

1) NAA/Cr
2) Cho/Cr
3) Cho/NAA
4) mI/Cr
5) Lactate and Lipids
6) Other prominent peaks in the spectrum.

Based on these ratios, the lesions were characterised as:

1. Benign/malignant
2. Provisional diagnosis

3. Grade of malignancy

4. Intralesional morphology (using metabolite maps)

All the patients having tumours were subsequently followed up for confirmation of diagnosis by histopathology. Patients with suspected infectious etiology were followed up by imaging (response to treatment).

**Statistical Analysis:**

The MR spectroscopic data in our study was assumed to follow normal distribution. The Sensitivity, Specificity, Positive predictive value, Negative predictive value and Diagnostic accuracy were calculated for neoplastic lesions. The level of significance was determined using the Student t-test. For comparison of the three groups (grades) of gliomas, ANOVA (Analysis of Variance) test was applied. Probability value (P) <0.05 was regarded as significant.
Results

Intracranial space occupying lesions in fifty patients, detected by MRI, were investigated with Proton MR Spectroscopy, using Multivoxel techniques. A limitation of MRS was inability to obtain adequate spectrum from lesions located peripherally, adjoining CSF or bone, and in lesions with large areas of hemorrhage or calcification. Adequate diagnostic spectrum was obtained from 47 of the 50 lesions included in the study.

In the present study -

- Most of the patients presenting with intracranial space occupying lesions were of the 40 to 59 years age group. This was also the most common age group of tumors.
- The majority of patients were males, forming 56% of the study population.
- The predominant cause of intracranial space occupying lesions was found to be tumors (52%) being the most prevalent. Infections formed 48% of the population.
- Irrespective of cause, the predominant presenting symptom was headache, seen in 90% of the patients, followed by seizures (33%). Even in infections, whether tuberculomas or abscesses, most of the patients presented with symptoms of raised intracranial tension or mass effect. Only a minority had fever or meningismus as the presenting complaint.
- The most common cause of intracranial space occupying lesions detected in the study were Gliomas (30%) and tuberculoma (30%).
- The most common tumors detected in the study were Gliomas (57%).
- The most common cause of infection detected in the study was TB (62%).
- Total of 50 patients were included in the study. On MR Spectroscopy, diagnostic spectrum was obtained in 47 patients (94%). In the remaining, spectrum obtained was poor due to interference from hemorrhage within the lesion (in 2 cases) or due to peripheral location close to bone (in the remaining 1).
- Mean Cho/ Cr ratio was high in gliomas, metastasis, PNET and meningiomas, while it was normal in infections.
- Highest Mean Cho/Cr value was seen in Glioma (3.19).
- Mean Cho/NAA ratio was high in all the lesions, with highest values seen in the Gliomas (2.70).
- Mean NAA/Cr ratio was below normal in all the lesions, lowest values seen in the meningiomas (1.19) and Gliomas (1.03).
- Lipid-lactate was seen in all high grade Gliomas and in Metastasis, and only in 66% of the meningiomas.
- Lipid-lactate peak was found in the high grade Gliomas, particularly in grade IV gliomas (100%).
• Alanine was seen all the meningiomas, but not in any other malignancy.
• Decrease choline levels resulting in Cho/NAA and Cho/Cr ratios lower than astrocytomas with peaks of lipid at 1 to 2ppm were seen in PNET.
• Elevated choline, decreased NAA and taurine peak at 3.4ppm was seen in Medulloblastoma.
• Lipid lactate peak was seen at 1.3ppm with high Cho/Cr ratios than astrocytomas in Ependymoma.
• Ethmoidal sinus Plasmacytoma with intracranial extension was included in our study as a follow up case post chemotherapy. MR spectroscopy in the intracranial part showed high Cho/NAA peak with high lipid lactate peak showing necrosis.
• Abscesses showed presence of lipid-lactate, acetone and aminoacid peaks, while acetone and aminoacids were not seen in Tuberculosis or NCC.
• Lipid-lactate peaks were seen in 100% of the cases of Tuberculosis, while being absent in neurocysticercosis.
• The Cho/Cr and Cho/NAA ratios show increase with increasing grade of malignancy, with maximum mean Cho/Cr ratio (4.19) and Cho/NAA ratio (2.92) seen in the Grade IV gliomas.
• NAA/Cr ratio was lower in the higher grade gliomas(1.01) than in the low grade gliomas, lowest in grade IV gliomas (1.01).
• ml/Cr ratio in the low grade gliomas was higher (0.88) than in the high grade gliomas (0.84).
• Mean choline, creatinine and NAA levels were found to be lower in the abscesses than in the other infectious lesions.
• The mean Cho/Cr and NAA/Cr ratios were higher in the tuberculous lesions than in NCC and Abscesses.
• Increased Cho/Cr (2.70±0.281) ratios were observed in neoplastic lesions as compared to non-neoplastic lesions Cho/Cr (1.59±0.146) with significant p value of 0.0012.
• Increased Cho/NAA (2.49±0.249) ratios were observed in neoplastic lesions as compared to non neoplastic lesions Cho/NAA(1.40±0.147) with significant p value of 0.0006.
• The Sensitivity and Specificity in detecting and characterisation of intracranial tumoral lesions are 95.83% and 92.31% respectively. The Positive predictive value and Negative predictive value 92% and 96% respectively. The Diagnostic accuracy of MRS combined with conventional MRI is 94% keeping Histopathology as Gold standard.
Fig. 19: 50 yr old man with Oligodendroglioma in left high parietal region showing choline and lipid lactate peak on MR Spectroscopy

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Fig. 22: 50 yr old man with Right Parieto-temporal PNET

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Fig. 23: 50 yr old man with Right Parieto-temporal PNET showing elevated Choline, suppressed NAA and high lipid lactate on MR Spectroscopy

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Fig. 24: 45 yr old lady with Tuberculoma in right parietal region

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**Fig. 25:** 45 yr old lady with Tuberculoma in right parietal region showing lipid lactate peak at 1.3 ppm on MR Spectroscopy

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Fig. 20: 60 yr old man with intracranial extension of Ethmoid sinus Plasmacytoma

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**Fig. 21:** 60 yr old man with intracranial extension of Ethmoid sinus Plasmacytoma showing high choline and lipid lactate peaks on MR Spectroscopy

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Fig. 1: 32 yr old man with Pyogenic Abscess in right parietal lobe

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**Fig. 2:** 32 yr old man with Pyogenic Abscess in right parietal lobe showing alanine, acetone peak at 1.5 ppm on MR Spectroscopy

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Fig. 3: 30 yr old man with Astrocytoma in left cerebellar hemisphere

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**Fig. 4:** 30 yr old man with Astrocytoma in left cerebellar hemisphere showing high choline peak on MR Spectroscopy

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Fig. 5: 24 yr old man with Supratentorial Interventricular Ependymoma

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**Fig. 6:** 24 yr old man with Supratentorial Interventricular Ependymoma showing Lipid-Lactate peak

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Fig. 7: 40 yr old female with left parieto-temporal GBM showing necrosis

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Fig. 8: 40 yr old lady with left parieto-temporal GBM showing necrosis and high choline peak on MR Spectroscopy

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**Fig. 9:** 45 yr old lady with Medulloblastoma in posterior fossa

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Fig. 10: 45 yr old lady with Medulloblastoma in posterior fossa showing taurine peak at 3.4 ppm on MR Spectroscopy

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Fig. 11: 65 yr old man with Meningioma in right high parietal region showing alanine peak at 1.5 ppm on MR Spectroscopy
**Fig. 12:** 68 yr old man with Left Occipital Metastasis

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Fig. 13: 68 yr old man with Left Occipital Metastasis showing high choline peak on MR Spectroscopy

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Fig. 14: 38 yr old man with left high parietal Colloidal Vesicular stage Neurocysticercosis

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**Fig. 15:** 38 yr old man with left high parietal Colloidal Vesicular stage Neurocysticercosis showing NAA peak on MRS

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**Fig. 16:** 35 yr old lady with F/up Post - Op case of Oligoastrocytoma involving right frontal region

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**Fig. 17:** 35 yr old lady with F/up Post - Op case of Oligoastrocytoma involving right frontal region showing high choline peak on MR Spectroscopy

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Fig. 18: 50 yr old man with Oligodendroglioma in left high parietal region

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Conclusion

Magnetic Resonance Spectroscopy can direct the surgeon to the most metabolically active part of the tumor for biopsy to obtain accurate grading of the malignancy. Magnetic Resonance Spectroscopy does not replace conventional MRI but compliments the information provided by it. It may provide information as a prognostic indicator, help follow progress of the disease and evaluate response to treatment.
References


