DOI: 10.7860/IJARS/2021/44799:2626

Original Article

Radiology Section

Magnetic Resonance Spectroscopy Analysis of Normal Cerebral White Matter at Different Regions

PENUMALLI NEELIMA[1], VADANA BALA MURALI KRISHNA[2], KANNEGANTI DHARMA TEJA[3], K CHANDRA SEKHARA RAO[4], BN CHANDER[5], PYLA SUDHA RANI[6]

ABSTRACT

Introduction: Conventional Magnetic Resonance Imaging (MRI) is a definitive method to check out structural and anatomical abnormalities of the brain, but it does not give any information regarding the functional or metabolic properties. Magnetic Resonance Spectroscopy (MRS) is widely used now-a-days for clinical applications and it also provides information about the metabolic properties of region of interest. The ideal way to analyse the magnetic resonance spectrum is to look at metabolite ratios such as NAA/Cr (N-Acetylaspartate and Creatine), Cho/Cr (Choline/Creatine) and NAA/Cho (N-Acetylaspartate/Choline).

Aim: To evaluate normal ratios of NAA/Cr, Cho/Cr and NAA/Cho in normal cerebral white matter in Indian population.

Materials and Methods: It was a prospective observational study carried out on 100 individuals with no history of trauma or known psychiatric illness who attended the Department of Radiodiagnosis in a period of two years from September 2010 to September 2012 in Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinnaoutpalli, Vijayawada, Andhra Pradesh, India. All data were collected, tabulated and statistically analysed using XLSTAT data analysis tool (Microsoft Excel) version 2010.

Results: The study was done in two cohorts. One includes study population of age range 20-35 years and other includes study population of age range 36-50 years. A total of 100 individuals were evaluated by performing MRS scan of which 65 were male (65%) and 35 were female (35%). The obtained ratios of NAA/Cr, Cho/Cr and NAA/Cho in 20-35 study age groups were 1.85, 0.81, 2.38, respectively. The obtained ratios of NAA/Cr, Cho/Cr and NAA/Cho in 36-50 study age group were 1.81, 0.84, 2.23, respectively.

Conclusion: The MRS is a non-invasive, radiation-free technique and is helpful to provide the metabolite information related to underlying dynamic physiology while being used as an adjuvant to MRI.

Keywords: Metabolite ratio, Multi voxel, Single voxel

INTRODUCTION

Spectroscopy is the study of the interaction between matter and radiated energy. Spectroscopy is the determination of the chemical composition of a substance by observing the spectrum of electromagnetic energy released from chemical sample or a tissue [1]. MRI uses resonance frequencies of nuclei of the atom that are at the lower end of electromagnetic spectrum, which range from 10MHz at 0.3T to about 300 MHz on 7.0T magnet. The MRI images are displayed on grey scale depending on relative signal strength of proton signals, when more number of protons is mobile; they are displayed as hyperintense signal on T2 sequence [2]. MRS is widely used now-a-days for clinical applications and it also provides information about the metabolic properties of region of interest. MRS which is an adjunct to MRI defines neurochemistry on a regional basis and displays the quantities as a spectrum. More the metabolite concentration, taller is the peak [1].

The ideal way to analyse the magnetic resonance spectrum is to look at metabolite ratios such as NAA/Cr, Cho/Cr and NAA/Cho. MRS data were obtained from the three main lobes of brain in the form of NAA/Cr, Cho/Cr and NAA/Cho ratios. The normal and abnormal ratios are depicted in [Table/Fig-1] [3].

The present study outlines to form a standard baseline of ratios for Indian population.

Metabolite ratios	Normal	Abnormal
NAA/Cr	2.0	<1.6
Cho/Cr	1.2	>1.5
NAA/Cho	1.6	<1.2

[Table/Fig-1]: Normal and abnormal ratios for any population [3].

MATERIALS AND METHODS

The present study was a prospective observational study which was done on 100 individuals with no history of trauma or known psychiatric illness who attended the Department of Radiodiagnosis for a period of two years from September 2010 to September 2012 at Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinnaoutapalli, Vijayawada, Andhra Pradesh, India. This study was approved by Institutional Ethical Committee via no. PG/09/2010. The purpose of the study was explained in detail to all the patients in the study and consent was taken. MRI and MRS were done on 1.5 TESLA PHILIPS ACHIEVA 16 channel machine. It is equipped with proton spectroscopy, NV coil (no voltage coil), software for spectral acquisition and post processing package.

Inclusion criteria: Computed Tomography (CT) scan/MRI scans showing normal brain study with no known abnormal psychological status, adult population pertaining to age group between 20 to 50 years irrespective of IQ status, both sexes included, with no relation to right or left handedness.

Exclusion criteria: Abnormal CT scan/MRI study of brain, patients with history of psychiatric problems and epilepsy/space occupying lesions/white matter disease, use of medication pertaining to any psychiatric illness and traumatic brain injury were excluded from the study.

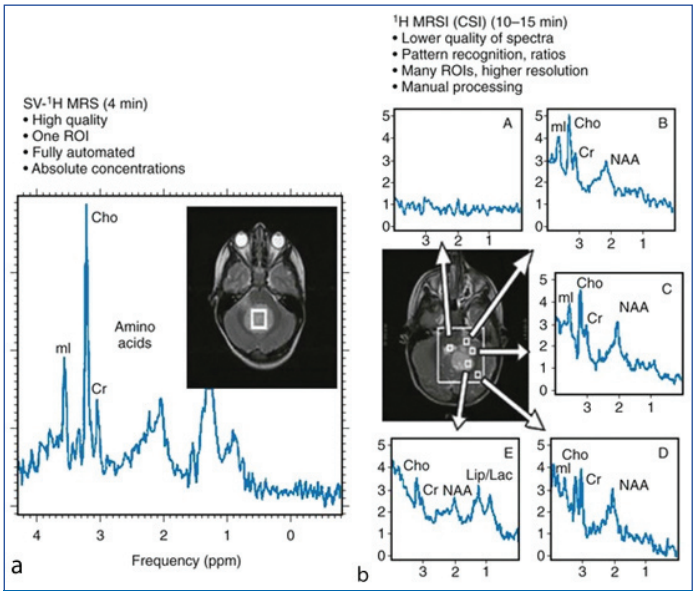
Scanning Technique

T2-weighted localiser images (TR/TE=2000/110, slice thickness 128 mm) were acquired in all planes (i.e., axial, saggital and coronal planes). Short TE (Echo Time) has a higher Signal-to-Noise Ratio (SNR) and less signal loss due to T2W and T1W than long TE. The

use of short TE results in a detection of more metabolite peaks such as glutamine-glutamate and myoinositol, which are not seen with longer TE [4,5]. Multiplanar reconstructions were taken in T1 weighted images. As a general rule, the single voxel, short TE technique is used to make the initial diagnosis, because the SNR is high and all metabolites are represented [6,7]. Localised MRS with single-voxel measuring 2 (AP)×2 (RL)×2 (FH)-(Anterior-posterior)×(Right-left)×(Feet-head) cm spectral band in the frontal, parietal and occipital lobes with high resolution (1000 Hz) was taken. Few differences between single voxel and multi voxel spectroscopy imaging are depicted in [Table/Fig-2] and acquisition of single voxel and multi voxel [8] is shown in [Table/Fig-3].

Single voxel spectroscopy	Multi voxel spectroscopy
Short TE	Long TE
One voxel	Multi voxel
Limited region	Many data collected
Fixed grid	Grid may be shifted after acquisition
More accurate	Voxel bleeding
Quantitative measurement	Spatial distribution

[Table/Fig-2]: Differences between single voxel and multi voxel [8].



[Table/Fig-3]: Pictorial representation of single voxel (a) and multi voxel (b) acquisition. Cho: Choline; Cr: creatine; CSI: Chemical shift imaging; Lip/Lac: Lipid/Lactate; MRS: Magnetic resonance spectroscopy; MRSI: Magnetic resonance spectroscopy imaging; NAA: N-acetylaspartate; ppm: parts per million; ROI: Region of interest; SV: Single voxel; 1H: Hydrogen; RF: Radio frequency

For every voxel position, a Point Resolved Spectroscopy (PRESS) sequence is carried out by using a 90-degree pulse followed by two 180-degree pulses (2000/110), with 128 signals was applied with water suppression. The most commonly used method to suppress the water peak is (Chemical Shift Selective-CHESS). The CHESS consists in applying three couples (90° RF pulses+dephasing gradients) in each spatial direction. The bandwidth of these RF pulses is narrow and centered on the resonance frequency of the water peak in order to saturate the water signal and save the signal from the other metabolites [6,9]. The patient was placed inside the gantry in supine position. NV- 16 channel coil was selected. Voxels are selected and scanning was done at TE 31 ms and TE 110 ms.

A homogeneous magnetic field is an important pre-requisite for obtaining resolvable spectra, as MRS requires a homogeneous magnetic field unlike MRI which requires gradient magnetic field. Shimming the field in the region of interest to the resonance of water assures the good homogeneity of the field. Hence, shimming is done. A Flip angle of 90° is taken. Total scan time is 15 minutes followed by post-processing.

STATISTICAL ANALYSIS

All data were collected, tabulated and statistically analysed using XLSTAT data analysis tool (Microsoft Excel) version 2010.

RESULTS

A total of 100 individuals were evaluated by performing MRS scan of which 65 were male (65%) and 35 were female (35%) illustrated in [Table/Fig-4]. In our study, the youngest person was of age 28 years and the eldest was of age 50 years. The mean age is 35.5±2.5 years.

Age (years)	Number of cases (n=100)	Male	Female	Percentage
20-35	52	35	17	52%
36-50	48	30	18	48%

[Table/Fig-4]: Age and sex distribution.

The obtained ratios of NAA/Cr, Cho/Cr and NAA/Cho in 20-35 years age group were sum averaged to 1.85, 0.81, 2.38, respectively. The obtained ratios of NAA/Cr, Cho/Cr and NAA/Cho in 36-50 years age group were sum averaged to 1.81, 0.84, 2.23, respectively [Table/Fig-5,6].

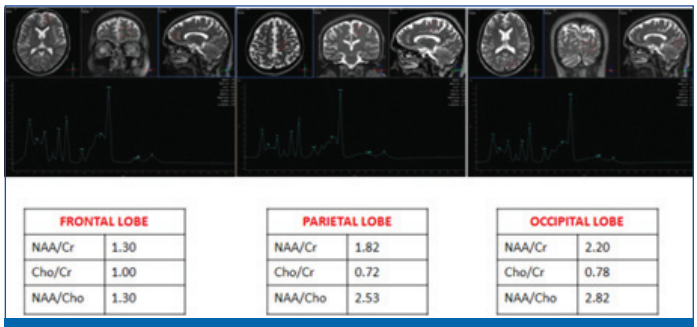
The representative images with metabolite ratios are depicted in [Table/Fig-7,8].

20-35 years (n=52)	Frontal lobe	Parietal lobe	Occipital lobe	Sum average
NAA/Cr	1.78	1.92	1.86	1.85
Cho/Cr	0.97	0.81	0.64	0.81
NAA/Cho	1.88	2.35	2.93	2.38

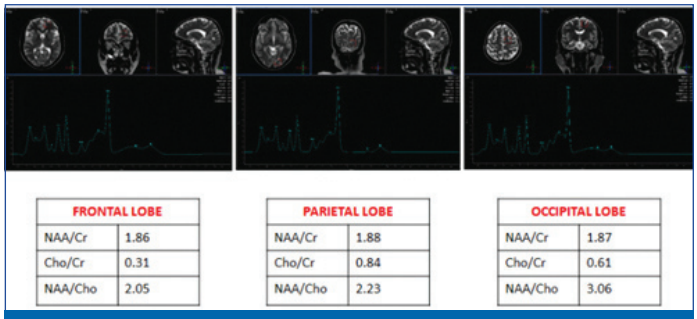
[Table/Fig-5]: Metabolite ratio in frontal, parietal and occipital lobes (20-35 years age group).

36-50 years (n=48)	Frontal lobe	Parietal lobe	Occipital lobe	Sum average
NAA/Cr	1.75	1.89	1.80	1.81
Cho/Cr	1.00	0.84	0.69	0.84
NAA/Cho	1.84	2.21	2.63	2.23

[Table/Fig-6]: Metabolite ratio in frontal, parietal and occipital lobes (36-50 years age group).



[Table/Fig-7]: A representative case of a 28-year-old female who has undergone MR spectroscopy, showing the metabolite ratios in frontal, parietal and occipital lobes in all the three planes axial, coronal and sagittal.



[Table/Fig-8]: A representative case of a 41-year-old male who has undergone MR spectroscopy, showing the metabolite ratios in frontal, parietal and occipital lobes in all the three planes axial, coronal and sagittal.

DISCUSSION

MRS is a non-invasive technique of MRI which is used to assess the chemical metabolites in the selected region of brain tissue.

Higher Field (H-MRS): H-MRS can be performed with both 3T and 1.5T. The 3T MRI has a reduced acquisition time and higher SNR than 1.5T MRI. SNR does not double with 3T H-MRS but increase in a linear way with the power of magnetic field [7]. A better spatial resolution increases the distance between peaks making it simple to differentiate between them. This is significant mainly for resonances from coupled spins such as glutamate, glutamine and myoinositol [5,8]. However, the metabolites line width also increases at higher magnetic field due to a markedly increase T2 relaxation time [4]. Proton spectra vary with the location of the prescribed voxel in which the spectrum is acquired. This should not be surprising, as the cytoarchitecture of the cerebral cortex differs considerably from one region of the cortex to the other [9]. Spectra obtained from the mature frontal cortex differ from those in the mature parietal cortex. Spectra obtained from the thalamus differ from those obtained from the striatum [10]. The brainstem and cerebellum have lower NAA/Cr. Values are lower in the basal nuclei (thalami, caudate, putamen) than in the cerebral white matter. Within the cerebral white matter, NAA/Cr is higher in the frontal than the parietal white matter. The choline peak is usually larger than creatine in white matter and creatine is usually larger than choline in grey matter [9,10].

The concentrations of NAA in grey and white matter are not significantly different for clinical purposes. However, most studies have shown that white matter has higher Choline levels whereas grey matter has higher Creatine levels [11]. The most outstanding difference is a caudal decrease in Cho in the cortex [12]. One of the studies found that grey matter has higher glutamate levels. The myoinositol levels are unclear but tends to be more in grey matter than white matter [13]. NAA levels are significantly higher in pons where as higher levels of Cho have been found in cerebellum and pons. Cr levels are found higher in cerebellum and low in pons when compared to supratentorial regions [14]. In cases of alzheimers and epilepsy, MRS of hippocampus is studied which showed anterio-posterior gradients of metabolites in the hippocampi. NAA is found to be lower whereas the concentration of Cho increases from posterior to anterior [15]. Studies have shown differences between the spectra of white and grey matter and supratentorial and infratentorial structures. Nevertheless, no significant asymmetries of metabolite spectra neither between the left and the right hemispheres nor between genders have been found [13].

Limitation(s)

Small study population, high spatial resolution, SNR and better chemical shift are noted at 3T MRI rather than 1.5T and in present study 1.5 T MRI was used.

CONCLUSION(S)

In recent years, MRS is more widely utilised for clinical applications and it also provides information about metabolic and functional properties of regions of interest. The demographic study done on 100 individuals over a period of two years determined the standard base line ratios of NAA/Cr, Cho/Cr and NAA/Cho in Indian population.

REFERENCES

[1] Lenkinski RE, Schnall MD. MR spectroscopy and the biochemical basis of neurological disease. In: Atlas SW, ed. Magnetic Resonance Imaging of the Brain and Spine. New York: Raven, 1991;1099–1121.
[2] Ramin SL, Tognola WA, Spotti AR. Proton magnetic resonance spectroscopy: Clinical applications in patients with brain lesion. Sao Paulo Med J. 2003;121(6):254-59.
[3] Hesselink J. Fundamentals of MR Spectroscopy. UCSD Neuro Web Center for Functional MRI. Web. 1 Jan 2015.
[4] Danielsen E. (Ed.), Ross B. (Ed.). (1999). Magnetic Resonance Spectroscopy Diagnosis of Neurological Diseases. Boca Raton: CRC Press, Chapter-5 https://doi.org/10.1201/9781482270105.
[5] Constantinidis I. MRS methodology. Adv Neurol. 2000;83:235-46.4; 235-42.
[6] Kreis R, Ernst T, Ross BD. Absolute quantitaion of water and metabolites in human brain, Metabolite concentrations. J Magnreson. 1993;102(1):09-19.
[7] Wiedermann D, Schuff N, Matson GB, Soher BJ, Du AT, Maudsley AA, et al. Short echo time multi-slice proton magnetic resonance spectroscopic imaging in human brain: Metabolite distributions and reliability. Magn Reson Imaging. 2001;19:1073-80.
[8] Magnetic Resonance Spectroscopy and Positron Emission Tomography, Ashok Panigrahy, Sunhee Kim and Stefan Bluml, Radiology key, Chapter 25.
[9] Martinez-Lage J, Ramos J, Puche A, Poza M. Extradural dermoids tumours of the posterior fossa. Arch Dis Child. 1997;77:427-30.
[10] Tsuruda JS, Chew WM, Moseley ME, Norman D. Diffusion weighted MR imaging of the brain: Value of differentiating between extraaxial cysts and Epidermoid tumor. AJNR Am J Neuroradiol. 1990;11:925-31.
[11] Brandao LA. MR Spectroscopy of the Brain, An Issue of Neuroimaging Clinics, Volume 23-3, 1st Edition, August 2013.
[12] Clinical MR Spectroscopy: Techniques and Applications, Peter B. Barker, Alberto Bizzi, Nicola De Stefano, Doris D. M. Lin, Rao Gullapalli, 2010.
[13] Zimmerman RA, Bilaniuk LT, Dolinskas C. Cranial CT of Epidermoid and congenital fatty tumors of maldevelopment origin. CT. 1979;3:40-47.
[14] MR Spectroscopy in Health and Disease. In: Manto M., Schmahmann JD, Rossi F, Gruol DL, Koibuchi N. (eds) Handbook of the Cerebellum and Cerebellar Disorders. Springer, Dordrecht, Öz G. (2013).
[15] Ross B, Michaelis T. Clinical application of magnetic resonance spectroscopy. Magnreson.1994;Q10:191-247.

PARTICULARS OF CONTRIBUTORS:

1. Consultant Radiologist, Department of Radiology, Pramodini Diagnostics, Vijayawada, Andhra Pradesh, India.
2. Assistant Professor, Department of Radiology, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India.
3. Assistant Professor, Department of Radiology, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India.
4. Professor and Head, Department of Radiology, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India.
5. Professor, Department of Radiology, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India.
6. Postgraduate, Department of Radiology, Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Vijayawada, Andhra Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Vadana Bala Murali Krishna,
Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation,
Chinnaoutpalli, Gannavaram, Vijayawada-521286, Andhra Pradesh, India.
E-mail: sudharanipyla@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 25, 2020
- Manual Googling: Oct 08, 2020
- iThenticate Software: Jan 16, 2021 (23%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Apr 24, 2020**
Date of Peer Review: **May 22, 2020**
Date of Acceptance: **Oct 09, 2020**
Date of Publishing: **Apr 01, 2021**