DIFFUSION TENSOR IMAGING IN CHILDREN WITH DEVELOPMENTAL DELAY

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Abstract-
Purpose: To determine whether diffusion-tensor magnetic resonance (MR) imaging can depict abnormalities in patients with a diagnosis of developmental delay but structurally normal brain MR imaging results.
Materials and methods: Thirty paediatric patients who received a diagnosis of developmental delay underwent brain MR examinations, including diffusion-tensor MR imaging. The MR findings in these patients were compared with those in 30 age-matched neurodevelopmentally healthy children. Mean diffusivity (MD) and anisotropy (FA) were measured bilaterally in regions of interest in anterior and posterior limbs of internal capsule, forceps minor and forceps major, pre and postcentral gyrus, frontal and temporal white matter, and genu, body & Splenium of corpus callosum. By using a one-tailed Student t test in the positive direction for MD and in the negative direction for anisotropy and P <0.05 to indicate a significant difference, the MD and FA values for children with developmental delay were compared with those for children who were neurodevelopmentally healthy.
Results: The results of our study revealed that there was a significant reduction in FA values in children with developmental delay, when compared to controls, mapped P values at genu of corpus callosum, body of corpus callosum, splenium of corpus callosum, right anterior limb of internal capsule, left anterior limb of internal capsule, right posterior limb of internal capsule, left posterior limb of internal capsule, right forceps minor, left forceps minor, left forceps major, left precentral gyri, right postcentral gyri, right frontal lobe white matter, left temporal lobe white matter and left temporal lobe white matter (p < 0.005). Also, there was significant increase in MD values in genu of corpus callosum, body of corpus callosum, right anterior limb of internal capsule, left anterior limb of internal capsule, right forceps minor, left forceps major, right postcentral gyri, left postcentral gyri, left frontal lobe white matter, left temporal lobe white matter respectively (p < 0.005).
Conclusion: In the children with developmental delay, diffusion-tensor MR imaging depicted decreases in anisotropy and increases in FA in the white matter fiber tracts, which appeared to be normal at conventional MR imaging.

***Key words*: Anisotropy, Children, Corpus callosum, Developmental delay, DTI, MRI**

INTRODUCTION:

Developmental delay [1] is defined as significant delay (more than two standard deviations below the mean [1] in one or more developmental domains. Developmental delays may occur in any or all of the major areas of child development: gross motor, fine motor, language and social[2]. It is a challenging pediatric clinical syndrome affecting nearly 3.8% of Indian children. It could be due to various etiologies resulting in embryological or fetal neuropathological changes [3]. Children diagnosed with developmental delay may require social counselling and physiotherapy in order to promote brain plasticity based on the severity of the damage.

Though Head computed tomography (CT), Ultrasonography, and conventional Magnetic Resonance Imaging (MRI) are helpful in diagnosing brain injury, they cannot quantify the degree of white matter damage to arrive at a prognosis [4,5,6] However, children with obvious motor and cognitive abnormalities often have unremarkable scans [7,8].

Magnetic Resonance (MR) diffusion tensor imaging (DTI) allows in vivo examination of the tissue microstructure, obtained by exploiting the properties of water diffusion. Diffusion tensor (DT) computed for each voxel allowed us to calculate the magnitude of water diffusion, reflected by the mean diffusivity (MD) and the degree of anisotropy, which is a measure of tissue organization.[9]

For acquiring images in MRI for developmental delay patients the sequences commonly used are T1, T2, Diffusion weighted imaging (DWI), Gradient Recombinant Echo (GRE) etc. Diffusion tensor imaging (DTI) permits evaluation pathologies pertaining to white matter using measures of diffusion anisotropy.

The parameters that are commonly used in DTI with respect to developmental delay, include fractional anisotropy (FA), and mean diffusivity (MD). Fractional anisotropy (FA) directly correlates with histological markers of myelination and a low FA value indicates myelin loss [9].

Mean diffusivity (MD) gives us valuable particulars about the rotational invariant magnitude of water diffusion occurring in the brain tissue [10]. With the help of these two quantitative measurements, it is possible to characterize the changes occurring in developmental delay.
In the majority of cases, patients with Developmental Delay have a "normal" MRI study in routine sequences.
Recent studies using DTI have shown detection of abnormalities in cerebral parenchyma of children showing Developmental Delay. Hence, DTI and related metrics can be used as non-invasive neuroimaging surrogates of Developmental Delay.
In light of emerging evidences, the present study intends to evaluate the cerebral morphology of patients diagnosed with Developmental Delay using routine as well as DT-MRI to statistically validate the above notion.

AIM AND OBJECTIVES

AIM:

To evaluate the role of Diffusion Tensor Imaging- derived metrics for assessment of deranged myelination in developmental delay children having normal routine MRI.

OBJECTIVES:

1. To assess the role of diffusion tensor imaging (DTI) in evaluating the white matter tracts in children with developmental delay and in normal controls.
2. To estimate the prevalence of abnormalities of the brain in cases on MRI and to apply diffusion tensor metrics to evaluate the microstructural damage in cases.

MATERIALS AND METHODS:

The study was approved by the scientific committee and institutional human ethical committee clearance obtained before commencing the study.

SOURCE OF STUDY POPULATION:

CASES:

30 children with clinical diagnosis of developmental delay were included in our study.

CONTROLS:

30 developmentally normal children were selected who were referred to our department for MR Brain imaging for other indications and was found to be normal.

STUDY DESIGN: Cross-sectional study

STUDY PERIOD:

The study was carried out in the Department of Radiodiagnosis at Rajarajeswari Medical College and Hospital, Bangalore. The study period was 1 year between (June 2022 to May 2023).

INCLUSION CRITERIA:

- Children with clinical diagnosis of developmental delay.
- Age group: 2 – 15 years

EXCLUSION CRITERIA:

- Patients having morphologically demonstrable abnormality on routine MRI sequences were also excluded.
- Patients with other confounding factors like history of past or active cranio-spinal infection, systemic illness, and any ongoing chronic illness were excluded.
- Children on metallic implants and cardiac pacemakers.
- Claustrophobic children.

METHOD OF DATA COLLECTION:

In this cross-sectional observational study, we have studied 30 patients in the age group between two years to fifteen years referred to MRI from paediatric OP with clinical suspicion of developmental delay and 30 age matched developmentally normal controls referred to our department for imaging for other reasons like history of trauma, facial hemangiomas, febrile seizures, etc. Informed consent was taken from the parents/guardians of these children. The MRI scan was done during night time when the child was asleep or the child was sedated giving oral syrup pedicloryl under the consent and presence of the paediatrician.
The study population were evaluated for

1. Detailed history taking.
2. Using a proforma specially designed for this study.
3. Routine MRI sequences.
4. DTI (Diffusion Tensor Imaging) sequence.

IMAGING TECHNIQUE:
DATA ACQUISISTION:
Examinations were conducted by using 1.5 T MR unit magnetom AERA (**Siemens**, Erlangen, **Germany**), 48 channel, 16 channel HNS coil
A pre-standardised protocol was followed for routine morphological imaging. High resolution anatomical images acquired with a T1 weighted image, T2 Weighted images, Flair (fluid attenuation inversion recovery sequences) 3D MPRAGE sequence for fusion of DTI data (POST PROCESSING)
Single shot EPI sequence, 24 directions, TE 100 ms, TR 8500 ms, matrix 128 x 128, FOV 230, 1.8 x 1.8 x 1.5 -2 voxel size, NEX 2, Grappa 2-,b values: 0 and 1000ns/mm^2 Eddy currents distortion correction. Total aquisition time: 2 min ,39 saxial slices: 4 mm, no gap parallel to AC-PC line.

IMAGE PROCESSING:
After acquiring the sequences, post processing done at Seimens workstation-using off tensor calculation and loading in Neuro-3D. In general, the DTI data analysis involves three major steps:
1. Data Preprocessing.

2. Derivation of tensor metrics.

3. Mapping ROIs.

For 30 cases and 30 controls, we obtained FA and MD values from 38 sites (ROIs) namely bilateral anterior and posterior limbs of internal capsule, bilateral forceps minor and forceps major, bilateral pre and postcentral gyrus, bilateral frontal and temporal white matter, and genu, body & Splenium of corpus callosum respectively.
DTI parameters like FA, MD and tract number values were extracted from particular ROI using "Draw" tool. "SEED" button was then used for drawing a single ROI or "AND" button for drawing multiple ROIs. ROI was drawn using multiple mouse button clicks and the parameters were extracted and saved as a text file, which was further transferred to excel file for statistical analysis.

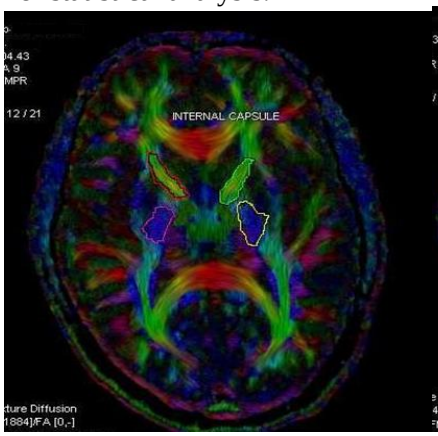

Figure 1

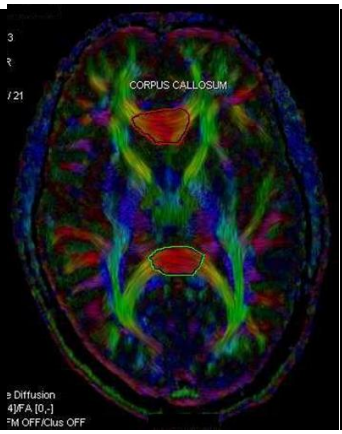

Figure 2

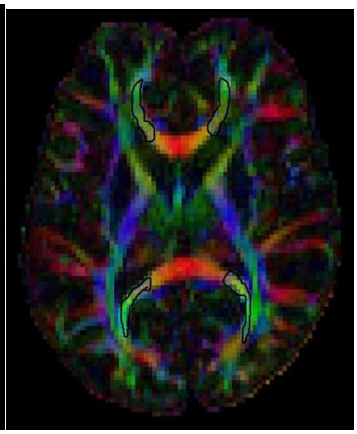
Figure 3

Figure – 1 Color coded DTI image with ROI in Bilateral anterior & posterior limb of internal capsule
Figure - 2 Color coded DTI image with ROI in Genu & Splenium of corpus callosum.
Figure - 3 Color coded DTI image with ROI in Bilateral Forceps major & minor

STATISTICAL ANALYSIS:
The collected data were analysed with IBM.SPSS (Statistical Package for Social Science) statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis was used for categorical variables and the mean & S.D were used for continuous variables. To find the significant difference between the bivariate samples in independent groups the Unpaired sample t-test was used. To find the significance in categorical data Chi-Square test was used. In all the above statistical tools the „p' value < 0.05 is considered as significant level.
The variables taken for quantitative assessment included, FA & MD values at the regions of bilateral anterior and posterior limbs of internal capsule, bilateral forceps minor and forceps major, bilateral pre and post central gyrus, bilateral frontal lobe, bilateral temporal lobe, Genu, body & splenium of corpus callosum respectively.

RESULTS:

Table 1: Comparison of Age distribution among cases and controls

Groups		N	Mean	S.D	t-value	P-value
AGE	Cases	30	6.60	3.255	0.544	0.588
	Controls	30	6.10	3.836		
# No Statistical Significance at P<0.05 level						

Mean age among the cases was 6.60±3.255 years and mean age among controls was 6.10±3.836 years. Both the groups were comparable to each other with respect to age without any significant difference between the groups. (p<0.05). (Table 1).

Table 2: Comparison of Gender distribution among cases and controls

Gender		Groups		Total	χ 2 - value	P-value
		Cases	Controls			
Male	Count	20	24	44	1.364	0.243
	%	66.7%	80.0%	73.3%		
Female	Count	10	6	16		
	%	33.3%	20.0%	26.7%		
Total	Count	30	30	60		
	%	100.0%	100.0%	100.0%		
	# No Statistical Significance at P<0.05 level					

Males (66.7%, among cases and 80% among controls) were predominant compared to females (33.3% among cases, 20% among controls) in both the groups Both the groups were similar to each other with respect to gender distribution without any significant difference between the groups. (p<0.05). (Table 2).

Table 3: Comparison of FA by Independent sample t-test

Groups		N	Mean	S.D	t-value	P-value
RTALICFA	Cases	30	.473	.060	6.355	0.0005 **
	Controls	30	.575	.064		
LTALICFA	Cases	30	.463	.050	7.479	0.0005 **
	Controls	30	.584	.074		
RTPLICFA	Cases	30	.633	.040	6.474	0.0005 **
	Controls	30	.717	.058		
LTPLICFA	Cases	30	.621	.035	7.921	0.0005 **
	Controls	30	.711	.052		
RTFMINFA	Cases	30	.450	.036		

	Controls	30	.521	.056	5.869	0.0005 **
LLFMINFA	**Cases**	30	.449	.034	5.586	0.0005 **
	Controls	30	.536	.078		
RTFMAJFA	**Cases**	30	.598	.035	1.401	0.171
	Controls	30	.639	.155		
LTFMAJFA	**Cases**	30	.569	.034	3.024	0.005 **
	Controls	30	.637	.119		
RTPRCGFA	**Cases**	30	.416	.048	1.168	0.248
	Controls	30	.432	.058		
LTPRCGFA	**Cases**	30	.379	.032	3.201	0.003 **
	Controls	30	.423	.067		
RTPOCGFA	**Cases**	30	.373	.031	8.479	0.0005 **
	Controls	30	.453	.041		
LTPOCGFA	**Cases**	30	.430	.039	2.242	0.029
	Controls	30	.454	.044		
RTFLFA	**Cases**	30	.464	.037	5.392	0.0005 **
	Controls	30	.393	.061		
LTFLFA	**Cases**	30	.363	.045	0.173	0.863 #
	Controls	30	.365	.049		
RTTLFA	**Cases**	30	.238	.042	6.403	0.0005 **
	Controls	30	.304	.038		
LTTLFA	**Cases**	30	.191	.017	10.661	0.0005 **
	Controls	30	.261	.031		
# No Sig.at P<0.05 and ** Highly Sig. at P < 0.01 level						

RTALICFA - Right Anterior Limb of Internal Capsule FA, **LTALICFA** - Left Anterior Limb of Internal Capsule FA,**RTPLICFA** - Right Posterior Limb of Internal Capsule FA, **LTPLICFA** - Left Posterior Limb of Internal Capsule FA, **RTFMINFA** - Right Forceps Minor FA, **LTFMINFA** - Left Forceps Minor FA, **RTFMAJFA** - Right Forceps Major FA, **LTFMAJFA** - Left Forceps Major FA, **RTPRCGFA** - Right Precentral Gyrus FA, **LTPRCGFA** - Left Precentral Gyrus FA, **RTPOCGFA** - Right Postcentral Gyrus FA, **LTPOCGFA** - Left Postcentral Gyrus FA

Table 4: Comparison of FA Central Independent sample t-test

Groups		**N**	**Mean**	**S.D**	**t-value**	**P-value**
CCGFA	**Cases**	30	.652	.040	10.180	0.0005 **
	Controls	30	.789	.062		
CCBFA	**Cases**	30	.383	.024	5.748	0.0005 **
	Controls	30	.427	.034		
CCSFA	**Cases**	30	.696	.037	7.479	0.0005 **

	Controls	30	.7804370	.04931203		
** Highly Sig. at P < 0.01 level						

CENTRAL CCGFA - Central Corpus Callosum Genu FA, **CENTRAL CCBFA -** Central Corpus Callosum Body FA, **CENTRAL CCSFA -** Central Corpus Callosum Splenium FA

Table 5: Comparison of MD by Independent sample t-test

Groups		**N**	**Mean**	**S.D**	**t-value**	**P-value**
RTALICMD	**Cases**	30	.00087	.00004	9.222	0.0005 **
	Controls	30	.00077	.00004		
LTALICMD	**Cases**	30	.00080	.00004	2.982	0.004 **
	Controls	30	.00077	.00004		
RTPLICMD	**Cases**	30	.00083	.00004	0.974	0.338 #
	Controls	30	.00378	.01659		
LFPLICMD	**Cases**	30	.00082	.00003	0.974	0.338 #
	Controls	30	.00377	.01659		
RTFMINMD	**Cases**	30	.00088	.00003	3.336	0.002 **
	Controls	30	.00083	.00007		
LLFMINMD	**Cases**	30	.00083	.00003	0.388	0.700 #
	Controls	30	.00083	.00005		
RTFMAJMD	**Cases**	30	.00089	.00005	2.021	0.050 #
	Controls	30	.00085	.00010		
LTFMAJMD	**Cases**	30	.00073	.00007	5.625	0.0005 **
	Controls	30	.00083	.00007		
RTPRCGMD	**Cases**	30	.00075	.00005	1.125	0.265 #
	Controls	30	.00111	.00176		
LTPRCGMD	**Cases**	30	.00083	.00006	0.841	0.404 #
	Controls	30	.00081	.00006		
RTPOCGMD	**Cases**	30	.00090	.00004	5.222	0.0005 **
	Controls	30	.00083	.00006		
LTPOCGMD	**Cases**	30	.00090	.00003	6.344	0.0005 **
	Controls	30	.00083	.00005		
RTFLMD	**Cases**	30	.00081	.00003	0.497	0.621 #
	Controls	30	.00081	.00006		
LTFLMD	**Cases**	30	.00087	.00004	4.467	0.0005 **
	Controls	30	.00082	.00005		
RTTLMD	**Cases**	30	.00087	.00005	2.176	0.034 #
	Controls	30	.00084	.00005		
	Cases	30	.00087	.00004		

LTTLMD	**Controls**	30	.00091	.00003	3.626	0.001 **
# No Sig. at P<0.05 and ** Highly Sig. at P < 0.01 level						

RTALICMD - Right Anterior Limb Of Internal Capsule MD, **LTALICMD** - Left Anterior Limb of Internal Capsule MD, **RTPLICMD** - Right Posterior Limb Of Internal Capsule MD, **LTPLICMD** - Left Posterior Limb Of Internal Capsule MD, **RTFMINMD** - Right Forceps Minor MD, **LTFMINMD** - Left Forceps Minor MD, **RTFMAJMD** - Right Forceps Major MD, **LTFMAJMD** - Left Forceps Major MD, **RTPRCGMD** - Right Precentral Gyrus MD, **LTPRCGMD** - Left Precentral Gyrus MD, **RTPOCGMD** - Right Postcentral Gyrus MD **LTPOCGMD** - Left Postcentral Gyrus MD

Table 6: Comparison of MD central by independent sample t-test

Groups		**N**	**Mean**	**S.D**	**t-value**	**P-value**
CCG	**Cases**	30	.00086	.00004	2.964	0.005 **
	Controls	30	.00081	.00008		
CCB	**Cases**	30	.00120	.00014	3.785	0.0005 **
	Controls	30	.00107	.00013		
CCS	**Cases**	30	.00061	.00003	1.081	0.288
	Controls	30	.00305	.01234		
# No Sig. at P<0.05 and ** Highly Sig. at P < 0.01 level						

CENTRAL CCGMD - Central Corpus Callosum Genu MD, **CENTRAL CCBMD** - Central Corpus Callosum Body MD, **CENTRAL CCSMD** - Central Corpus Callosum Splenium MD

GLOBAL EVALUATION

The measured variables in 19 regions were analysed and compared with the corresponding contralateral areas of same patient and with comparable areas of controls. The overall analysis included 19 ROIs with 38 variables, i.e.; an FA value and MA value, for each region. This exercise was repeated both for cases as well as controls, and revealed the ROIs in 15 anatomically distinct areas (78.9%) to have at least one statistically significant variable. These 15 areas gave 25 (65.78%) statistically significant variables, of which 15 (60%) were FA values while 10 variables (40%) were MD values [Tables 3 and 4].

REGIONAL EVALUATION:

Internal capsule:

FA showed statistically significant difference between cases and controls in both anterior and posterior limbs of the internal capsule [Tables 3]. MD showed significant difference between cases and controls in both right and left anterior limbs of the internal capsule. MD in the posterior limb remained insignificant in the present study. [Tables 5].

Corpus callosum:

The regions and variables that turned out to be of significance included FA in the genu, body and Splenium of corpus callosum (lower in cases than in controls) [Tables 3], MD in genu and body of corpus callosum (higher in cases than in controls). [Tables 5].

Forceps minor and major:

FA showed statistically significant difference between cases and controls in right and left forceps minor and left forceps major. [Tables 3]. MD showed statistically significance in right forceps minor and left forceps major. [Table 5].

Precentral and postcentral gyrus:

FA showed statistically significant difference between cases and controls in left precentral gyri and right post centra gyri. [Tables 3]. MD showed statistically significance in both right and left postcentral gyrus. [Tables 5].

Frontal lobe white matter:

FA showed statistically significant difference between cases and controls in right frontal lobe. [Tables 3]. MD showed statistically significance in left frontal lobe. [Tables 5].

Temporal lobe white matter:
FA showed statistically significant difference between cases and controls in bilateral temporal lobe. [Tables 3]. MD showed statistically significance in left temporal lobe. [Table 5].
Central Corpus Callosum Genu:
FA showed statistically significant difference between cases and controls in central CCG. [Table 4]. MD showed statistically significance in central CCG. [Table 6].
Central Corpus Callosum Body:
FA showed statistically significant difference between cases and controls in central CCB. [Table 4].MD showed statistically significance in central CCB. [Table 6].
Central Corpus Callosum Splenium
FA showed statistically significant difference between cases and controls in central CCS. [Table 4]. MD showed insignificant difference between cases and controls in central CCS. [Table 6].

Discussion:
There are various studies on Magnetic resonance imaging of the brain in children with developmental delay wherein they have studied about the prevalence of various abnormalities. Also, studies using diffusion tensor imaging in children with morphologically normal MRI has been reported. [11,12] Diffusion tensor imaging has also been applied to specific etiologies like hypoxic ischemic encephalopathy [13], periventricular leukomalacia [14] developmental anomalies like corpus callosal agenesis, dysgenesis [15] metabolic disorders [16] and in children with cerebral palsy[17] and they have reported its usefulness in the evaluation of such children. Few case reports on children with phakomatoses [18] and Peng et al. [19] presenting with developmental delay has also been reported. Developmental delay is a challenging disorder that requires long term counselling and rehabilitation.
In the majority of cases, patients with Developmental Delay have a "normal" MRI study in routine sequences. Recent studies using DTI have shown detection of abnormalities in cerebral parenchyma of children showing Developmental Delay. Hence, DTI and related metrics can be used as non-invasive neuroimaging surrogates of Developmental Delay.
In this cross-sectional observational study, we have studied 30 patients in the age group between two years to fifteen years referred to MRI from paediatric OP with clinical suspicion of developmental delay and 30 age matched developmentally normal controls referred to our department for imaging for other reasons like history of trauma, facial hemangiomas, febrile seizures, etc. Informed consent was taken from the parents/guardians of these children. The MRI scan was done during night time when the child was asleep or the child was sedated giving oral syrup pedicloryl under the consent and presence of the paediatrician.
Fiber tractography is a novel MR technique, with which it is possible to relatively predict the specific tracts involved in children with developmental delay. This probabilistic tracking is based on the fibers and the anatomical location.
Color coded maps are generated from the tensor images and each white matter fiber tract is assigned a specific color based on the direction of its fibers.
In our study the mean age of the case group was 6.6+/- 3.2 years and the control group was
6.1+/- 3.8, with a p value of 0.588 (insignificant). Hence the age distribution is similar in case and control groups respectively. This was similar to a study by Verma et al. in which no significant difference was noted between the case and control with respect to age and gender composition with a $\chi 2 = 0.217$ (P = 0.642).
A male preponderance was noted amongst the cases in the present study which was similar to a study by Verma et al.[12]

Quantitative evaluation:
The data set expresses the impression that most areas evaluated on a random basis, with MD and FA measurements, would give at least one useful measurement, which would enable one to give a tentative suggestion as to the need of further regional analysis. If a combination of at least three regions with a specified variable in each is included, the sensitivity for filtering out suspicious cases increases to 90%.
This fact is important from the point of view that regional assessment is a time- and labor-intensive task and may need significant attention on the part of a dedicated neuroradiologist. This may disturb the workflow in a high-volume department if performed in each case.

Regional evaluation:
Quantitative measurements of white matter integrity were assessed using parameters such as FA and MD. The FA values in brain range from 0 to 1. We obtained FA and MD values from 38 sites (ROIs) namely bilateral anterior and posterior limbs of internal capsule, bilateral forceps minor and forceps major, bilateral pre and postcentral gyrus, bilateral frontal and temporal white matter, and genu, body & splenium of corpus callosum respectively.
The results of our study revealed that there was a significant reduction in FA values in children with developmental delay, when compared to controls, mapped P values at genu of corpus callosum (0.0005), body of corpus callosum (0.0005), splenium of corpus callosum (0.0001), right anterior limb of internal capsule (0.0005), left anterior limb of

internal capsule (0.0005), right posterior limb of internal capsule (0.005), left posterior limb of internal capsule(0.0005), right forceps minor (0.001), left forceps minor (0.001), left forceps major (0.005), left precentral gyri (0.003), right postcentral gyri (0.0005), right frontal lobe white matter (0.0005), left temporal lobe white matter (0.0005), and left temporal lobe white matter (0.0005) respectively.

The above findings correlated based on the principle involved in tensor imaging in which water diffusion is faster parallel to the white matter bundles than perpendicular to it. Our findings were in accordance with the study done by Christopher.G.Filippi et al. [20] wherein they have noticed significant reduction in FA values in genu & splenium of corpus callosum, frontal & parietal white matter, anterior limb of internal capsule and centrum semiovale respectively. In another study conducted by Ashish Verma et al. [12] in children with developmental delay have reported significant decreases in FA values at the regions of corpus callosum, bilateral forceps minor & forceps major, bilateral parietal lobes and bilateral posterior limb internal capsule.

A similar study by Ding et al.[21] showed the importance of DTI in evaluating microstructural brain abnormalities in children with inconspicuous findings in conventional MRI. The study reported a reduction of the FA values (0.66 in patients vs. 0.74 in controls) at the genu of the Corpus Callosum were found in patients. Reductions of the fibre numbers (5,464 in patients vs. 8,886 in controls) and volumes (3,415 ml in patients vs. 5,235 ml in controls) of the Corpus Callosum were found only in patients older than 5 years. These findings were consistent with the present study.

In a study by Kim et al.[22] which was conducted among children with language impairment, the fractional anisotropy values of children with language impairments showed a statistically significant reduction in the genu of the corpus callosum compared with the normal control group which was in accordance to this study.

Though we did not observe statistically significant difference in FA values at right forceps major, right precentral gyri, left post central gyri and left frontal lobe white matter between the case and control groups, FA values of cases seemed to be reduced when compared to those of control group.

Also, there was significant increase in MD values in genu of corpus callosum (P value 0.005), body of corpus callosum (0.0005), right anterior limb of internal capsule (0.0005), left anterior limb of internal capsule (0.004), right forceps minor (0.002), left forceps major (0.0005), right postcentral gyri (0.0005), left postcentral gyri (0.0005) left frontal lobe white matter (0.0005), left temporal lobe white matter (0.001) respectively.

As enumerated above with the help of DTI, microstructural damage can be quantified, using FA and MD values. Also, it has been suggested that FA values are more accurate predictors of microstructural integrity over MD values and thus can more accurately characterize the microstructural changes.

Conclusion:

In this study, among the children with developmental delay, diffusion-tensor MR imaging depicted decreases in anisotropy and increases in FA in the white matter fibre tracts, which appeared to be normal at conventional MR imaging. DTI helps in quantification of white matter integrity, and the qualitative changes which in correlation with clinical data can be used in planning specific rehabilitation measures. With DTI, identification of 3D relationships between different tracts and between tracts and grey matter structures is made possible, which would play a key role in influencing patient's prognosis.

With the advent of diagonal tract propagation and NODDI (Neurite Orientation Dispersion and Density Imaging) sequences, most of the limitations with DTI can be addressed. DTI is expected to be a valuable tool in the future with which disease treatment planning, detection of preclinical markers, and microstructural abnormalities could also be achieved.

Furthermore, it is also anticipated that the structural-functional correlates provided by DTI studies will become part of the clinic's imaging routine.

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