IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 2 Ser.3 (February. 2023), PP 37-48
www.iosrjournals.org

Role of diffusion tensor imaging in the evaluation of white matter tracts in space occupying lesions.

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Abstract
Background: *Diffusion tensor imaging (DTI) is a magnetic resonance (MR) imaging technique that helps to characterize the orientational features of the diffusion of water molecules. It measures the restricted diffusion of water in tissues to produce neural tract images, which help in the identification of pathological and normal-appearing areas in the brain. Tractography helps to show the orientation and association of white matter fibre tracts (WMFT) even in the presence of brain edema, along with their displacement, infiltration,and/or disruption.*
Materials and Methods: *The present study is a cross-sectional, observational study undertaken to assess the "Role of diffusion tensor imaging in the evaluation of white matter tracts in space-occupying lesions," with patients being referred to the department of radiology at NRI Medical College and GH Chinakakani.*
A 1.5 Tesla MRI was used to examine all of the study participants.
Results:*In our study, out of 50 patients, 62% were males and 38% were females. Infiltration of tracts was seen in 38% of the 50 cases, displacement in 38% of the cases, disruption in 24% of the cases, and edema in 14% of the cases. There was no significant decrease in FA values as per T tests.*
Conclusions: *Diffusion tensor imaging (DTI) is very helpful in identifying tract disruption, infiltration, displacement, and edema. This information helps neurosurgeons in surgical planning.*
Keywords *DTI, white matterfibre tracts (WMFT), intracranial space occupying lesions, tractography, apparent diffusion coefficient (ADC), fractional anisotropy (FA), computed tomography(CT), and magnetic resonance imaging(MRI)*

Date of Submission: 22-01-2023 Date of Acceptance: 05-02-2023

I. Introduction: TheConcept of DTI

Random thermal motion, also known as Brownian motion, is the molecular diffusion of water in three dimensions.Isotropy is uniformity in all directions, and it occurs when water molecule diffusion is completely uninhibited.When there is a directionality in water diffusion and the movement of water is not random, anisotropy occurs.The more anisotropy there is, the more directional and linear the diffusion of water molecules will be. Water molecules may diffuse through space differently depending on tissue components, type, structure, architecture, and integrity. All of these principles allow for clinically significant imaging.Water movement along axons is measured by DTI[1].

Diffusion tensor imaging (DTI) is a magnetic resonance (MR) imaging technique used to characterise the orientational features of water molecule diffusion and generate neural tract images by measuring restricted diffusion of water in tissues. It also generates apparent diffusion coefficient (ADC) and fractional anisotropy (FA), which aid in distinguishing between pathological and normal brain areas. MR tractography was extremely useful in assessing the trajectories of vital white matter tracts of the brain in a non-invasive manner. Tractography can show the orientation and association of white matter fibre tracts (WMFT) even when there is brain edema, as well as their displacement, infiltration, and/or disruption.

Infectious, neoplastic, and inflammatory causes can all result in intracranial space-occupying lesions (ICSOL). A reliable etiology is essential for timely diagnosis and intervention[2]. With the advent of new research in India over the last 20 years, it became clear that brain tumors are as common in India as they are in the rest of

the world[3]. The incidence of CNS tumors ranges from 10 to 17 per 100,000 people for intracranial tumors and 1 to 2 per 100,000 people for intraspinal tumors[4].

Many patients with intracranial masses present a significant diagnostic challenge due to their atypical presentation caused by haemorrhage, artery occlusion, and cerebral infarction. In such cases, it is critical to use modern neuro-radiological procedures such as CT scans and MRIs to detect these lesions. As a result, accurate characterization and localization of ICSOL are critical. As a result, the current study was initiated.

In DWI, data is collected using voxels. A tensor is a voxel with scalar values that form a vector, which is how DTI got its name[5].

DTI can determine the diffusion of water along an axon in a variety of directions, the most common of which are 6, 9, 25, 33, and 90, with 33 directions and above increasing confidence in the reliability.

Given that diffusion anisotropy represents white matter (WM) bundles, these bundles of aligned voxels can be parcellated, yielding a 3D map of WMBT. Tractography is the process of tracking fibres by starting with a voxel and progressing through an anisotropic path until reaching isotropy. This can provide information about brain connectivity[6,7,8].

Commonly used DTI measures include fractional anisotropy (FA), ADC radial, and axial diffusivity.DTI uses mean diffusivity for molecular diffusion rate, FA for summative direction of diffusion that provides a prominent vector, axial diffusivity for rate of diffusion that is parallel to the main vector, and radial diffusivity for diffusion rate that is perpendicular to the main vector.

FA is highly sensitive to changes in microstructure. But it can also be nonspecific to the change in the cause. Mean diffusivity quantifies cellular density. An increase in mean diffusivity means the presence of edema or necrosis. Radial diffusivity quantifies myelin neuropathology and raises in demyelination. Axial diffusivity quantifies axonal degeneration and increases in brain maturation[9,10].

FA is measured using the region of interest (ROI) method, whole-brain analysis, or tract-based spatial analysis.

Highly compact WM fiber tracts can show a higher degree of anisotropy, and DTI helps in identifying various alterations in WM structures. It also helps in preoperative neurosurgical planning by showing tumor effects on adjacent WM tracts. If a tumor has only displaced WM tracts, it has normal FA values compared with the abnormal side.

FA increases if the tumor has infiltrated the WM tract.

When the tumor has disrupted a WMFT, it is not detectable on FA or directionally encoded color maps[11,12,13].

II. Materials and Methods

Method of data collection: The present study is a cross-sectional, observational study undertaken to assess the role of diffusion tensor imaging in the evaluation of space-occupying lesions being referred to the department of radiology, NRI Medical College, and GH Chinnakakani.

Study design: Cross-sectional, observational study

Study location: Department of Radiology, NRI Medical College, and GH Chinakakani.

Study duration: December 2021 to December 2022

Sample size:50

Sample size calculation:

The sample size is calculated as follows:

$N=Z^2PQ/E^2$

N-Samplesize

P-Prevalence

P=0.01%

Q=1-P

E-Error: 0.65%,

99.99% confidence limits

N=47

47 is the minimum size

So, we included 50 patients in this study, considering few lost to follow up cases.All 50 patients provided consent for the study.

Subjects and selection method: All patients above the age of 18 were selected and investigated on a 1.5-Tesla GE Signa Excite MRI system with a phased array head coil using conventional MRI sequences and DTI sequences. Both normal and abnormal sides of the brain were evaluated using tractography.Age, gender, displacement, infiltration, and disruption of tracts were assessed for all patients.

Inclusion criteria:
1. Patients with intracranial space-occupying lesions
2. Any gender.
3. Patients aged above 18 years
4. Patients who provided informed consent to participate in the study

Exclusion criteria:
1. Pregnant and lactating women
2. Patients with cardiac pacemakers, prosthetic heart valves, cochlear implants, or any metallic implants
3. Patients with a history of claustrophobia

Imaging protocol The scanning protocol is axial sections of T1, T2, FLAIR, DWI, SWI images, and DTI sequences in 25 directions.

Statistical analysis The data collected was entered into Excel 2019, and analysis was carried out using Excel 2019 and software called Epi Info version 7.2.5. The results were expressed in the form of descriptive and inferential statistics.

A probability value below 0.05 was considered statistically significant. Frequencies, percentages were also used. Continuous variables were calculated using the mean and standard deviation (SD). Categorical parameters were determined using the chi-square test. Numerical values were assessed using the T test.

III. Results

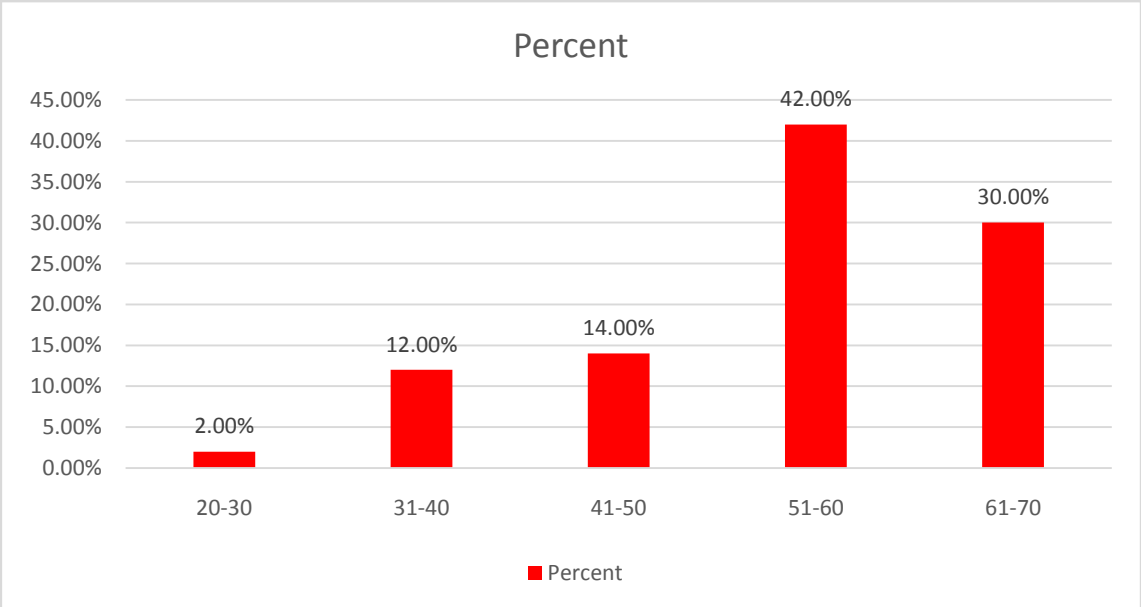
Age distribution:

42% of patients were aged 51–60 years. 30% of patients were aged 61–70 years; 14% were aged 41–50 years; and 12% were aged 31–40 years.

Table 1: Age distribution

AGE GROUP	Frequency	Percent	Cum. Percent
21-30	1	2.00%	2.00%
31-40	6	12.00%	14.00%
41-50	7	14.00%	28.00%
51-60	21	42.00%	70.00%
61-70	15	30.00%	100.00%
Total	50	100.00%	100.00%

Graph 1: Age distribution



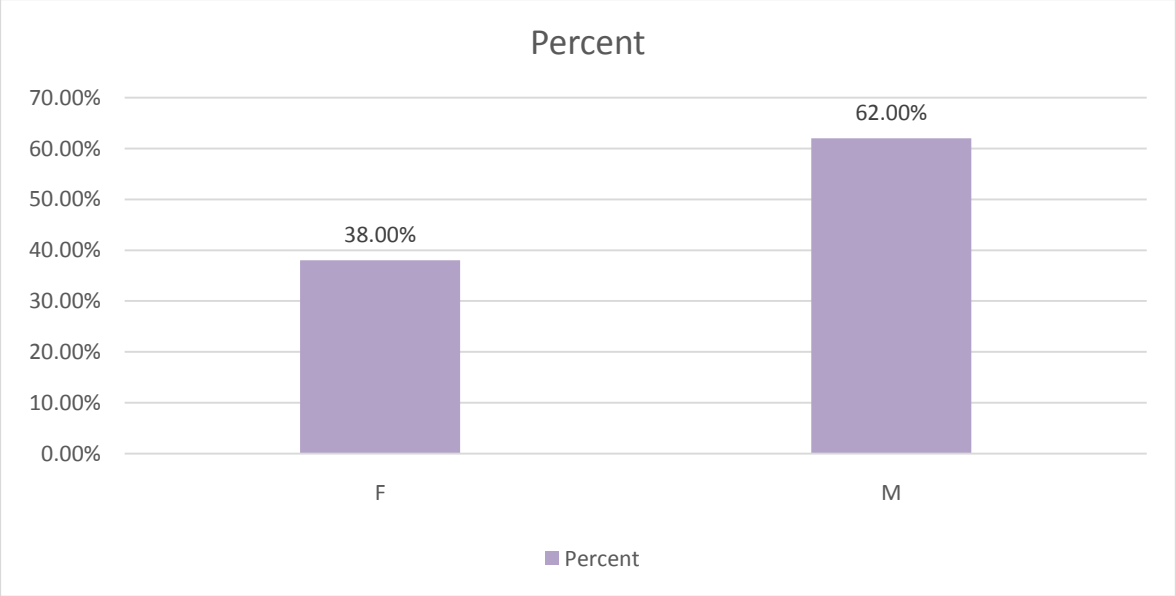
Mean age:
The mean age of patients was 53.3 ± 10.9 years.
Age of patients ranged from 19 to 68 years.
The median age was 55 years.

Gender distribution:
62% of the patients were males and only 38% were females in the current study.

Table 2: Gender of patients

SEX	Frequency	Percent	Cum. Percent
F	19	38.00%	38.00%
M	31	62.00%	100.00%
Total	50	100.00%	100.00%

Graph 2: Gender of patients

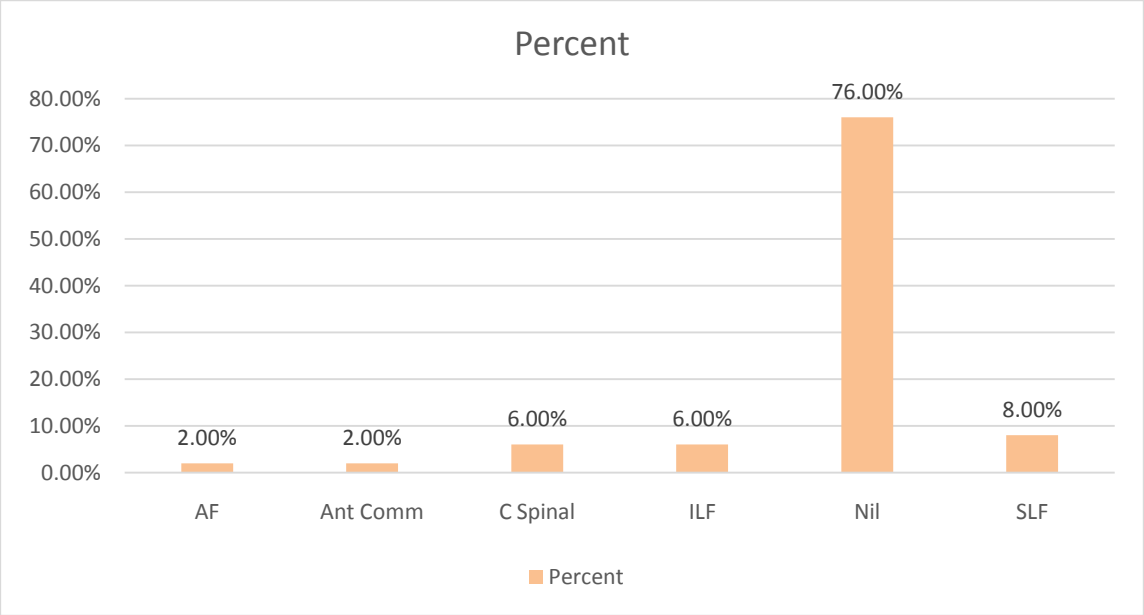


Disruption of tracts:
Disruption of tracts was seen in 24% of patients.
8% of patients had a disruption in the superior longitudinal fasciculus.
2% had disruption in the anterior commissure.
2% had disruption in the arcuate fibres.
6% had disruption in the corticospinal tract.
6% had disruption in the inferior longitudinal fasciculus.

Table 3: Disruption of tracts

DISRUPTION	Frequency	Percent
Arcuate fibres	1	2.00%
Ant Commissure	1	2.00%
Cortico Spinal	3	6.00%
Inf Long Fasciculus	3	6.00%
Nil	38	76.00%
Sup Long Fasciculus	4	8.00%
Total	50	100.00%

Graph 3: Disruption of tracts



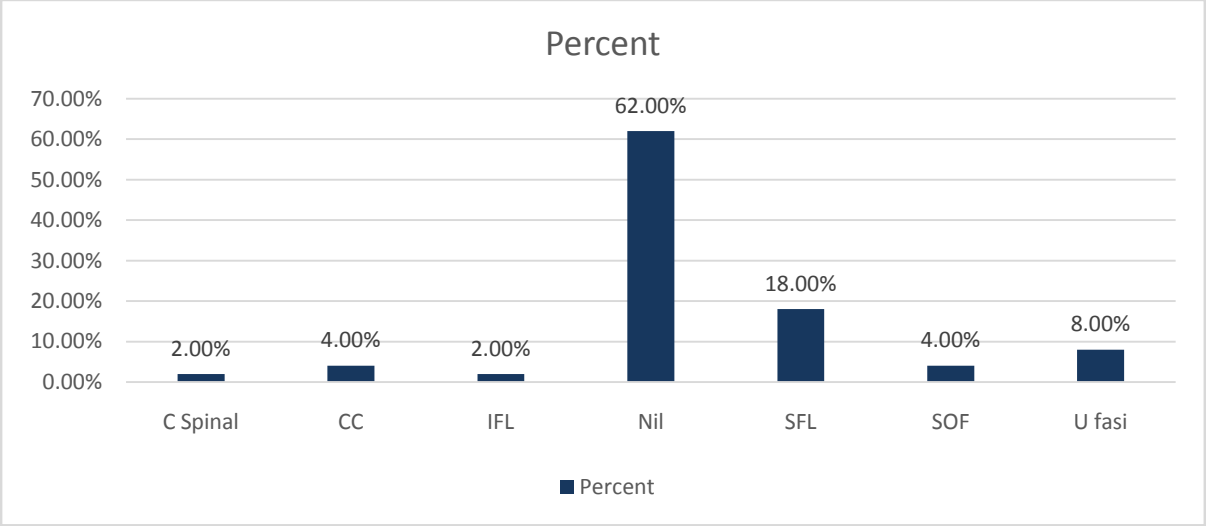
Infiltration of tracts:

Infiltration was seen among 38% of patients. Superior longitudinal fasciculus was infiltrated among 18% of patients, uncinate fasciculus was infiltrated in 8% of patients, inferior longitudinal fasciculus was infiltrated in 2% of patients, cortical spinal tract was infiltrated in 2% of patients, corpus callosum was infiltrated in 4% of patients.

Table 4: Infiltration of tracts

INFILTRATION	Frequency	Percent
C Spinal	1	2.00%
Corpus callosum	2	4.00%
Inf longitudinal fasciculus	1	2.00%
Nil	31	62.00%
Sup Longitudinal fasciculus	9	18.00%
Sup occipito frontal	2	4.00%
Uncinate fasciculus	4	8.00%
Total	50	100.00%

Graph 4: Infiltration of tracts



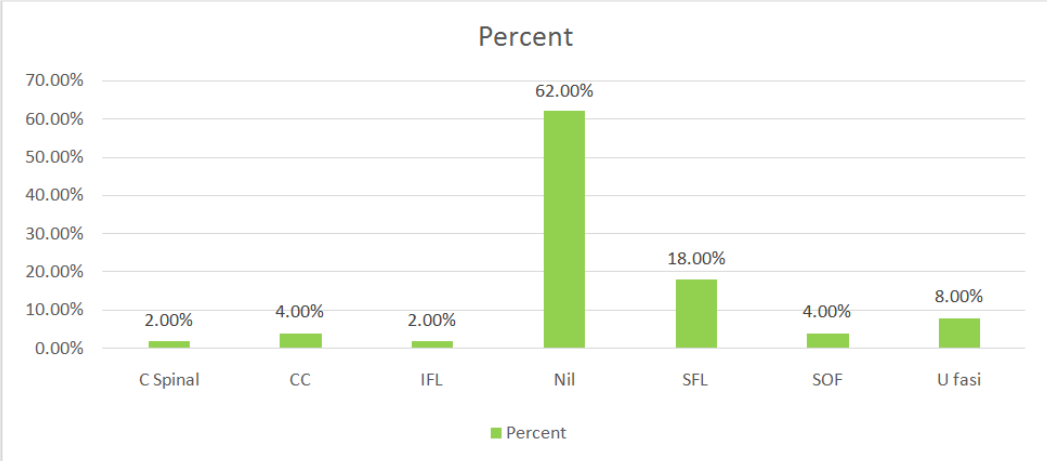
Displacement of tracts:

Displacement was seen among 38% of patients in the current study. Corticospinal tracts were displaced in 2% of patients, corpus callosum was displaced in 4% of patients, inferior long fasciculus was displaced in 2% patients; superior longitudinal fasciculus in 18% of patients, uncinate fasciculus was displaced in 8% of patients.

Table 5: Displacement of tracts

DISPLACEMENT	Frequency	Percent
Corticospinal	1	2.00%
Corpus callosum	2	4.00%
Inf long fasciculus	1	2.00%
Nil	31	62.00%
Sup long fasciculus	9	18.00%
Sup occipito frontal	2	4.00%
Uncinate fasciculus	4	8.00%
Total	50	100.00%

Graph 5: Displacement of tracts

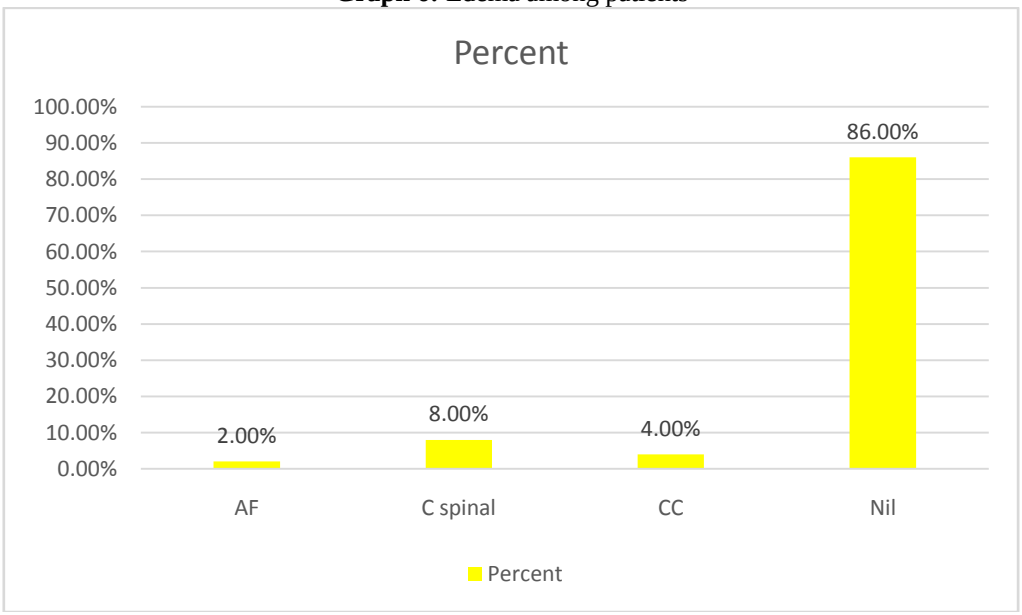


Edema: Edema was seen in 14% of patients.

Table 6: Edema in patients

EDEMA	Frequency	Percent
Arcuate fibres	1	2.00%
C spinal	4	8.00%
Corpus callosum	2	4.00%
Nil	43	86.00%
Total	50	100.00%

Graph 6: Edema among patients



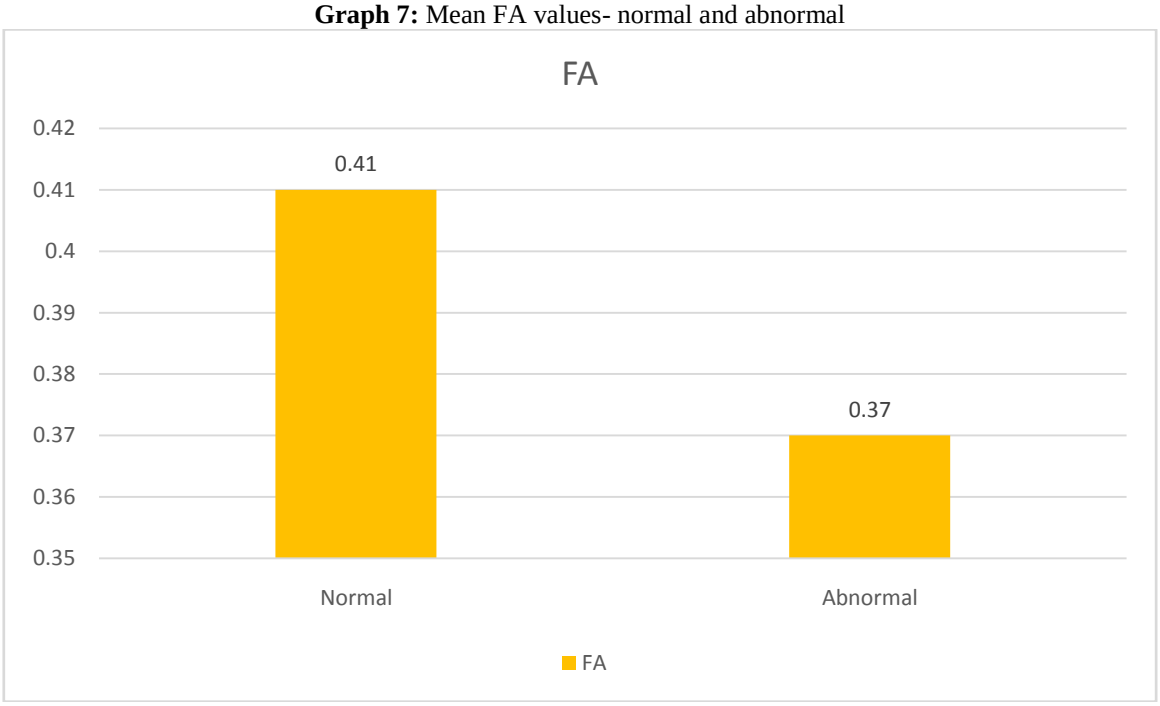
Mean FA values normal and abnormal comparison:
There was no significant difference in FA values between normal and abnormal sides, as per T test. (p=0.10). The mean FA value in normal side was 0.41 and it was 0.37 in abnormal side.

Table 7: Mean FA values- normal and abnormal

FA values normal N1: 50 df1 = N - 1 = 50 - 1 = 49 M1: 0.41 SS1: 1.31 s21 = SS1/(N - 1) = 1.31/(50-1) = 0.03 FA Values abnormal N2: 50 df2 = N - 1 = 50 - 1 = 49 M2: 0.37 SS2: 1.71 s22 = SS2/(N - 1) = 1.71/(50-1) = 0.03

The t-value is 1.25549. The p-value is .106143. The result is not significant at $p < .05$.

Graph 7: Mean FA values- normal and abnormal



Comparison between ADC values- normal and abnormal sides:
There was no significant difference in ADC values between normal and abnormal sides, as per T tests. (p=0.09).

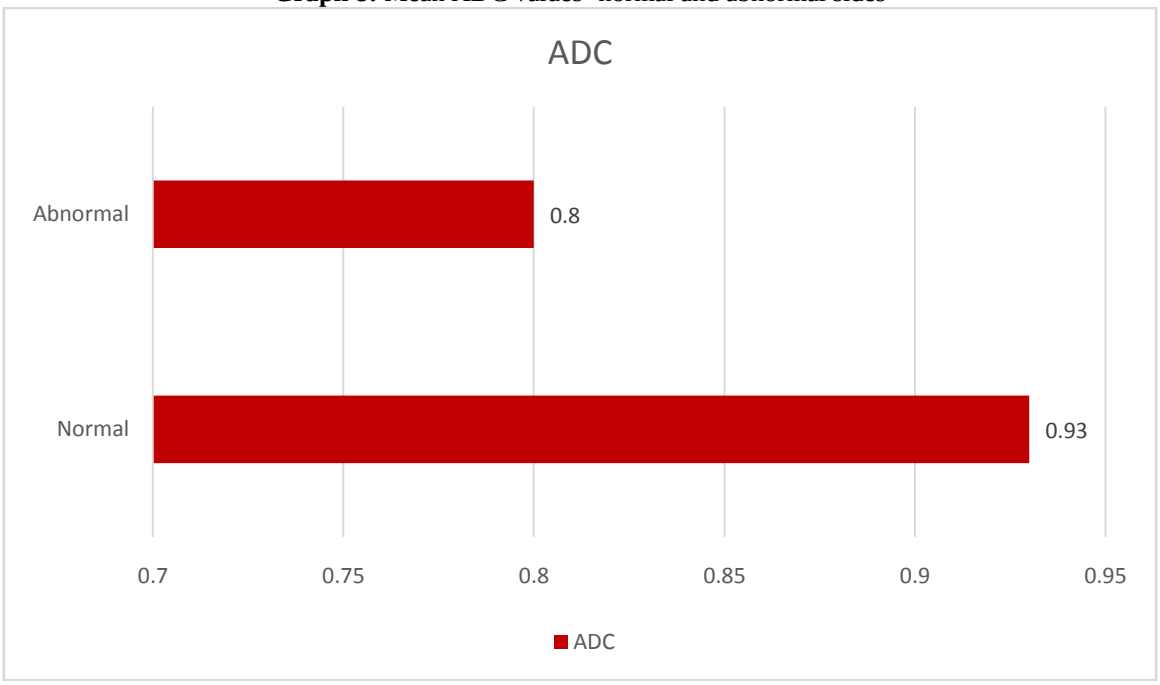
Table 8: Mean ADC values- normal and abnormal sides

Difference Scores Calculations ADC normal N1: 50 df1 = N - 1 = 50 - 1 = 49 M1: 0.93 SS1: 20.98 s21 = SS1/(N - 1) = 20.98/(50-1) = 0.43 ADC abnormal

N2: 50
df2 = N - 1 = 50 - 1 = 49
M2: 0.8
SS2: 5.19
s22 = SS2/(N - 1) = 5.19/(50-1) = 0.11

The t-value is 1.32207. The p-value is .094612. The result is not significant at p < .05.

Graph 8: Mean ADC values- normal and abnormal sides



Comparison of FA between neoplastic and non-neoplastic lesions:
There was no significant difference in mean abnormal FA between neoplastic and non-neoplastic lesions, as per T test(p=0.06). The mean FA in neoplastic lesions was 0.4 and it was 0.3 in non-neoplastic lesions.

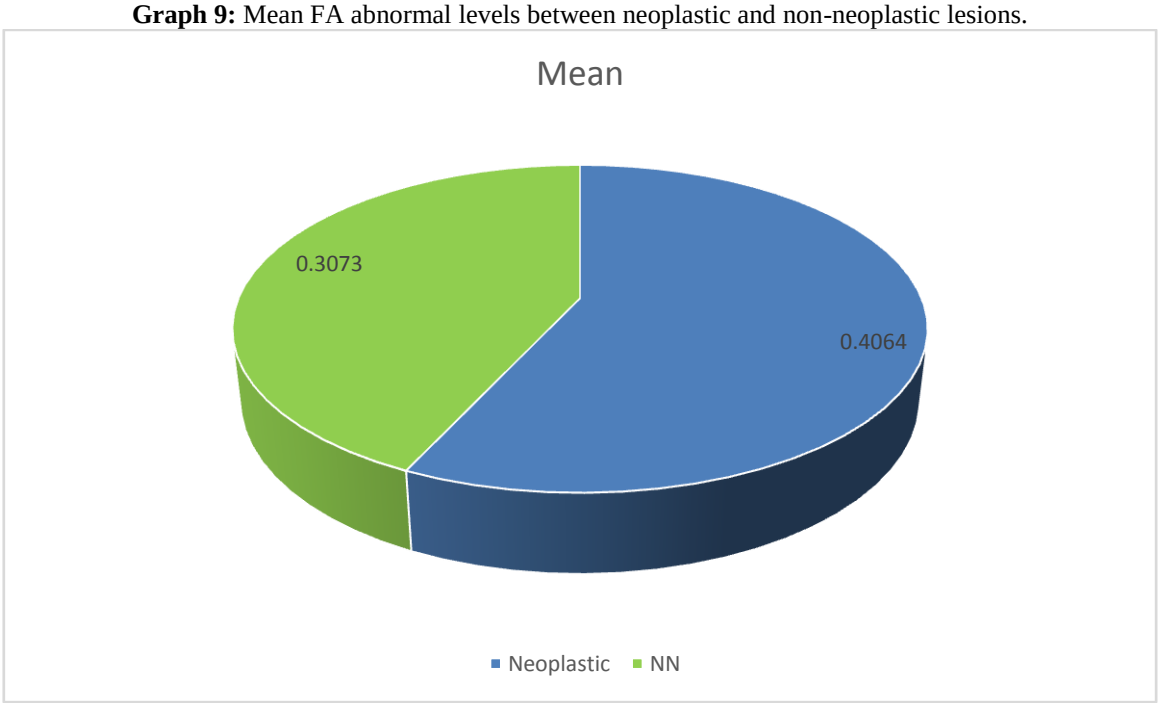
Table 9: Mean FA abnormal levels between neoplastic and non-neoplastic lesions.

Descriptive Statistics for Each Value of Crosstab Variable					
Group	Obs	Total	Mean	Variance	StdDev
Neoplastic	30.0000	12.1920	0.4064	0.0337	0.1837
NN	20.0000	6.1460	0.3073	0.0326	0.1804

T-Test

Method	Variances	DF	t Value	Pr> |t|
Pooled	Equal	48	1.88	0.0659

Graph 9: Mean FA abnormal levels between neoplastic and non-neoplastic lesions.



Comparison of ADC between neoplastic and non-neoplastic lesions:
There was no significant difference in mean abnormal ADC between neoplastic and non-neoplastic lesions, as per T test(p=0.43). The mean ADC in neoplastic lesions was 0.76 and it was 0.84 in non-neoplastic lesions.

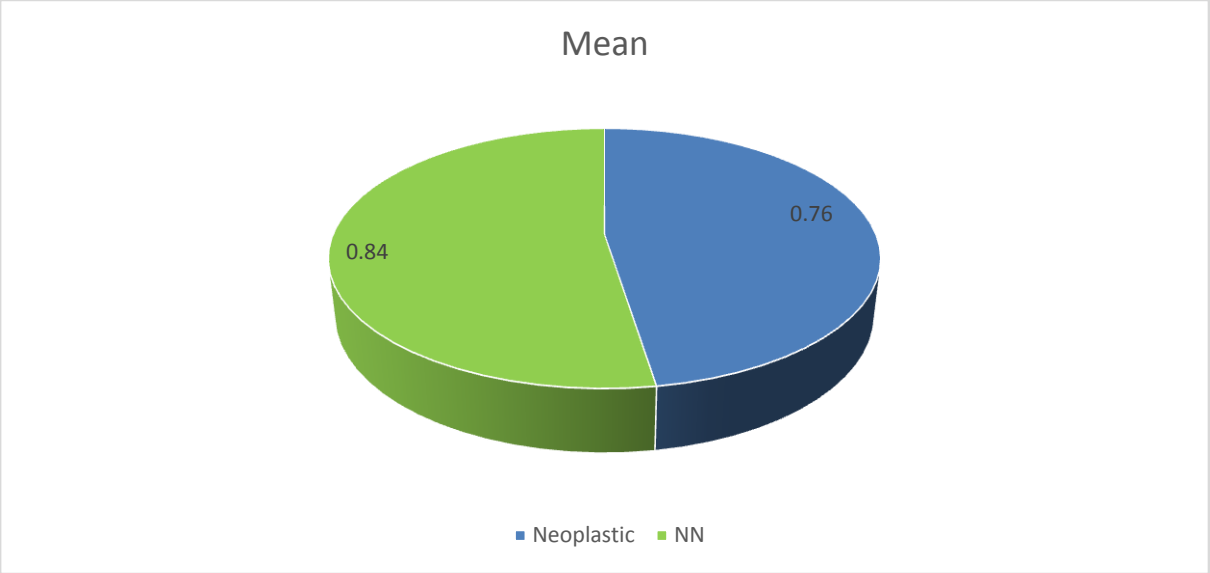
Table 10: Mean ADC abnormal levels between neoplastic and non-neoplastic lesions.

Descriptive Statistics for Each Value of Crosstab Variable					
Group	Obs	Total	Mean	Variance	StdDev
Neoplastic	30.0000	23.0510	0.7684	0.0456	0.2136
NN	20.0000	16.8550	0.8428	0.2002	0.4475

T-Test

Method	Variances	DF	t Value	Pr> |t|
Pooled	Equal	48	-0.79	0.4344

Graph 10: Mean ADC abnormal levels between neoplastic and non-neoplastic lesions.



IV. Discussion

Age of patients:

42% of patients were aged 51-60 years. 30% of patients were aged 61-70 years, 14% were aged 41-50 years and 12% were aged 31-40 years. The mean age of patients was 53.3±10.9 years.

Patients ranged in age from 18 to 68 years. The median age was 55 years among the 50 patients included in the current study with intracranial space occupying lesions.

62% of the patients were males and only 38% were females in the current study. This suggests that ICSOL were more common among males and after the age of 50 years.

Disruption, displacement and infiltration of tracts:

Tract disruption occurred in 24% of patients. 8% of patients had a disruption in the superior longitudinal fasciculus. 2% had disruption in the anterior commissure. 2% had disruptions in arcuate fibres. 6% had disruptions in corticospinal tract. 6% had disruption in inferior longitudinal fasciculus in the current study.

Infiltration was seen among 38% of patients. Superior longitudinal fasciculus was infiltrated among 18% of patients, uncinate fasciculus was infiltrated in 8% of patients, inferior longitudinal fasciculus was infiltrated in 2% of patients, cortical spinal tract was infiltrated in 2% of patients, corpus callosum was infiltrated in 4% of patients in the current study.

Displacement was seen among 38% of patients in the current study. Corticospinal tracts were displaced in 2% of patients; the corpus callosum was displaced in 4% of patients; the inferior long fasciculus was displaced in 2% of patients; the superior longitudinal fasciculus was displaced in 18% of patients; and the uncinate fasciculus was displaced in 8% of patients. Edema was seen in 14% of patients in the current study, among the 50 patients included.

Yen YS[14] determined the extent and severity of WM tract modifications with the help of DTI to know preoperative viability or resectability. The study included 21 patients. 86 tracts with 43 white matter-paired lesions and 43 contralateral lesions (normal or control) were assessed. Among the 43 tracts with lesions, 5 had edema, 9 had infiltration, 18 had displacement, and 11 had disruption. There was a significant difference in mean FA values between the normal and abnormal sides of lesions. This finding was in contrast to the current study, which found no significant difference. Edema FA and disruption FA were found to be less compared to displacement FA. These findings correlated with those in the current study.The study concluded thatanalysis of DTI may provide insight into whether WM tracts are salvageable preoperatively.

Whiteweret al [15] conducted a study on 9 patients with brain tumors. All underwent DTI before tumour excision. White matter tract oedema was seen in 2 patients, infiltration was seen in 2 patients; displacement was seen in 5 patients; and disruption was seen in 2 patients. Displacement was most commonly seen.

FA VALUES:

There was no significant difference in FA values between normal and abnormal sides, as per T test(p=0.10).Mean FA value in normal side was 0.41 and it was 0.37 in abnormal side. There was no significant difference in mean abnormal FA between neoplastic and non-neoplastic lesions, as per T test(p=0.06). The mean FA in neoplastic lesions was 0.4, and it was 0.3 in non-neoplastic lesions in the current study.

ML WHITE[16] study showed that the mean FA value for grade II tumorsas 0.124, which was significantly less than grade IV tumors, with mean value 0.171.There was no significant difference in mean FA between grade 2 and grade 3 tumors. Kruskal-Walli's test compared the FA range between various grades of tumors. FA range for grade II tumors (0.084) was significantly less compared to range of grade III and grade IV tumors and enhanced component (0.182). The FA range in grade II tumors was less compared to the non-enhanced component. There was a significant correlation between the FA range and the maximum FA seen. In contrast, there is only a mild correlation between the FA range and the minimum FA.

In study of **Xiang le**[17], 22 subjects were included. Among them, 12 had brain tuberculosis- tuberculoma and 10 had cerebral toxoplasmosis. Results were done using ANOVA and the T test. ADC and FA values were measured. There were significant differences among the 3 regions between subjects with tuberculoma and patients with toxoplasmosis. There was also a significant difference in FA values between solid areas and edematous areas. FA values of solid areas in DTI showed infiltrative changes of WM fibres in the lesion areas.

V.Conclusion

The current study looked at DTI results from patients who had intracranial space-occupying lesions.We discovered that DTI is extremely useful in detecting tract disruption, infiltration, displacement, and edema. This information aids in the planning of surgery.DTI can help distinguish between neoplastic and non-neoplastic lesions, as well as between primary and metastatic lesions.

DTI has the potential to be included in imaging guidelines for intracranial lesions and treatment planning, but more research is needed to determine the depth and breadth of its application.

The research is self-funded.
There were no conflicts of interest.

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Dr. Siri ChandanaMamillapalli, et. al. "Role of diffusion tensor imaging in the evaluation of white matter tracts in space occupying lesions." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 22(2), 2023, pp. 37-48.