



Comparison of signal intensities of white matter and gray matter on t2w and flair axial sequences in magnetic resonance imaging of brain

Boora Navreet¹, Virmani Nitish^{2*}, Yadav Kripanand³, Sharma BB⁴

¹ Assistant Professor, College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India

² Assistant Professor, Faculty of Allied Health Sciences, SGT University, Gurugram, Haryana, India

³ Assistant Professor, College of Allied Health, Maharishi Markandeshwar University, Mullana, Ambala, Haryana, India

⁴ Professor and HOD, Faculty of Medicine & Health Sciences, SGT University, Gurugram, Haryana, India

Abstract

Purpose: The aim is to compare the signal intensities of T2W and FLAIR sequences and evaluate the age factor causing the variations in signal intensities in MRI brain.

Methodology: Study involves the collection of data those age and pathology factors affecting White Matter (W.M) and Grey Matter (G.M) signal intensities in T2W and FLAIR on MRI Brain. Different areas selected on MR image include Corona Radiate for W.M fibers and caudate, Putamen, lenticular internal capsule and thalami for G.M to measure the signal intensities.

Result: This study contains a total 64 patients, sub distributed in four different age groups. Correlation of signal intensities of W.M on T2W and FLAIR sequences and G.M were seen individually. Linear correlation per age group with signal intensities on T2W & FLAIR, Karl Pearson's Correlation and one-way ANOVA methods applied. In less than 20 years ($p=0.912$), 20 to 40 years ($p=0.290$), 40 to 60 years ($p=0.248$) and more than 60 years ($p=0.777$) age the relationship was found the positive significant of signal intensities of W.M on T2W & FLAIR sequences. G.M signal intensities on T2W & FLAIR sequences on less than 20 years ($p=0.944$), age group between 40 to 60 years ($p=0.158$) and above 60 years ($p=0.761$) were also found positive significance relationship. But non-significance in the age group 20 to 40 years ($p=0.000$).

Conclusion: Study concluded that signal intensity values show variation with age and dependent on various pathologies. Hence signal intensity measurement can play an important role in proper diagnosis.

Keywords: signal intensity, T1W, FLAIR, MRI, grey matter, white matter

Introduction

MRI is the medical imaging process which uses a magnet to reconstruct images of the body tissues and helping in differentiate between normal tissues and abnormal tissue. Magnetic Resonance Imaging (MRI) was being used for physical and chemical analysis. Then in 1971 "Raymond Damadian" showed that nuclear magnetic relaxation times of tissues and tumors differed motivating scientists to use MRI to study disease, many scientists over the next 20 year developed MRI into the technology that we know and use today^[1, 2, 3].

Signal Intensity

When describing most MRI sequences, we refer to the shade of grey of tissues or fluid with the word intensity, leading to the absolute terms are high signal intensity will appear white, Intermediate signal intensity grey, and Low signal intensity black. Often, also can refer the appearance by relative terms like Hyperintense is brighter than the thing we are comparing it to, Isointense is similar brightness as the thing we are comparing it to, Hypointense

is darker than the thing we are comparing it to^[4].

T2W Image Characteristics

Tissues with long T2 values that produce the highest magnetization and appear brightest on the image. Long time of repetition (TR) values 2000-6000ms and long time to echo (TE) 100-150ms (Figure 1 & 2) is being used in T2W. Image appearance of T2W is the easiest way to identify, fluid-filled spaces in the human body e.g. free fluid in the abdomen, fluid in the gall bladder and common bile duct, Cerebrospinal fluid (CSF) in the brain ventricles and spinal canal, fluid in the urinary tract and urinary bladder, synovial fluid in joints, edema or any other pathological fluid collection in the human body. Appearance of fluid is bright on T2 weighted images. Water content in tissues normally increase in pathological processes. The added water component appearance in a increase signal on T2 and loss of signal on T1 weighted images. Consequently, pathological processes are usually bright on T2 weighted images and dark on T1 weighted images^[5, 6].

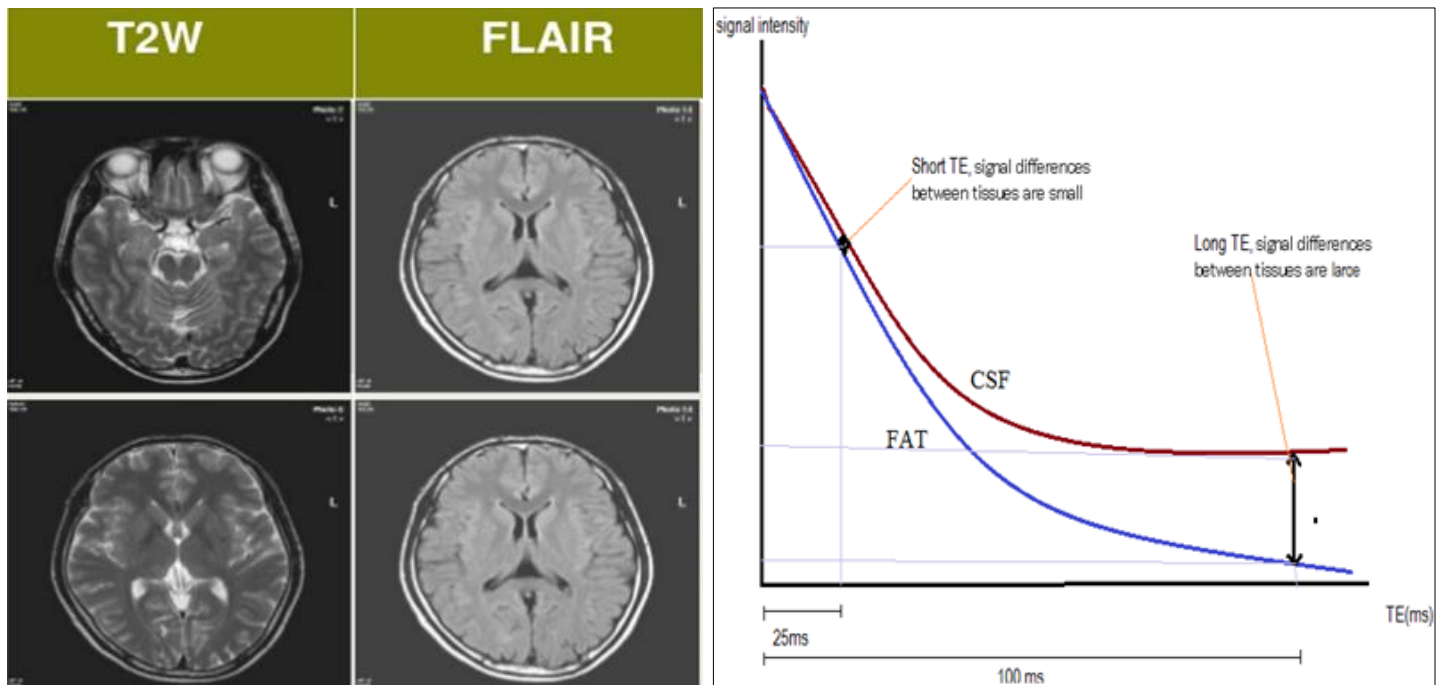


Fig 1 & 2: Shows the Images of T2W and FLAIR sequences & Graph of Signal Intensities

Fluid Attenuation Inversion Recovery (FLAIR) Image characteristics: FLAIR is a sequence in which use of long inversion time (Figure 1 & 2). This removes the signal from the cerebrospinal fluid from the resulting images. Brain tissue on FLAIR images, therefore, appears similar to T2 weighted images with grey matter brighter than white matter and White matter - darker than gray. MRI image appearance is the easiest way to identify FLAIR images is to look for CSF filled spaces and lesions or other pathological processes in the brain or spinal cord. Fluids normally appear dark and lesions or other pathological processes appear bright on the image. Appearance of fluid is suppressed on T2 FLAIR images. As water content increases according to pathological processes in the tissues. The added water contents appearance is increase signal on FLAIR images. Consequently, pathological processes are usually bright on FLAIR images [7, 8].

Need of Study

In our hospital, we routinely get requisitions for various MRI Brain scans. However various studies had been done so far to evaluate the signal intensities. But no study was done on the values of signal intensities on MRI Brain sequences. Signal intensity values give an idea about to diagnose the problems, many factors can cause variations in white matter and grey matter signal intensity. That's why this topic is chosen to perform a

study.

AIM

The aim is to compare the signal intensities of T2W and FLAIR sequences and evaluate the age factor causing the variations in signal intensities in MRI brain.

Materials and Methods

This is a Quantitative, Correlated and Prospective study involving the collection of age and pathology factors affecting White Matter and Grey Matter signal intensities in T2W and FLAIR Sequences of MR Imaging over a period of **6 months** in the radiology department. Data were collected from the entire population, i.e. MRI Brain cases randomly selected and signal intensities of W.M. & G.M. calculated and compared on T2W and FLAIR sequences and other medical details, clinical history was also recorded. A total number of 64 Prospective cases taken, during this time the data of MR Brain cases collected on a daily basis along with the clinical history of patients and their information like name, age, sex, etc. Different areas selected on MR image include Corona Radiate for white matter fibers and caudate, Putamen, lenticular internal capsule and thalami for grey matter to measure the signal intensities. The selected area is 48-52 pixels and 98-102 pixels for grey matter and white matter respectively, as shown in figure 3 & 4.

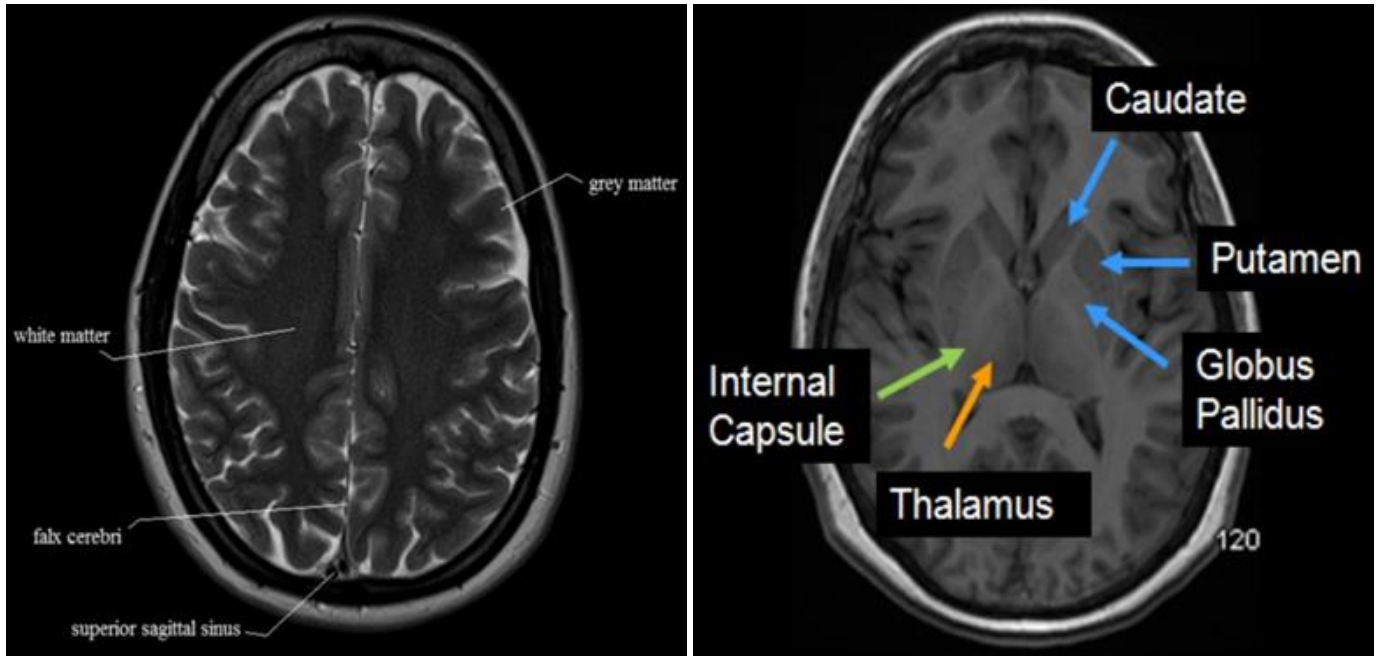


Fig 3 & 4: different white matter & Gray matter areas on MRI Brain image

In total 64 patient data set both male (43) and female (21) were included in this study with different age and further categorized in different age groups like less than 20 years old, 20 to 40 years, 40 to 60 years and more than 60 years old age groups. Out of total 12 patient

(male 9 and female 3) were in less than 20 years, 25 patients (male 18 & female 7) were in 20 to 40 years, 16 patients (male 9 & female 7) were in 40 to 60 years and 11 patients (male 7 & female 4) were in more than 60 years age group as shown in Figure-5

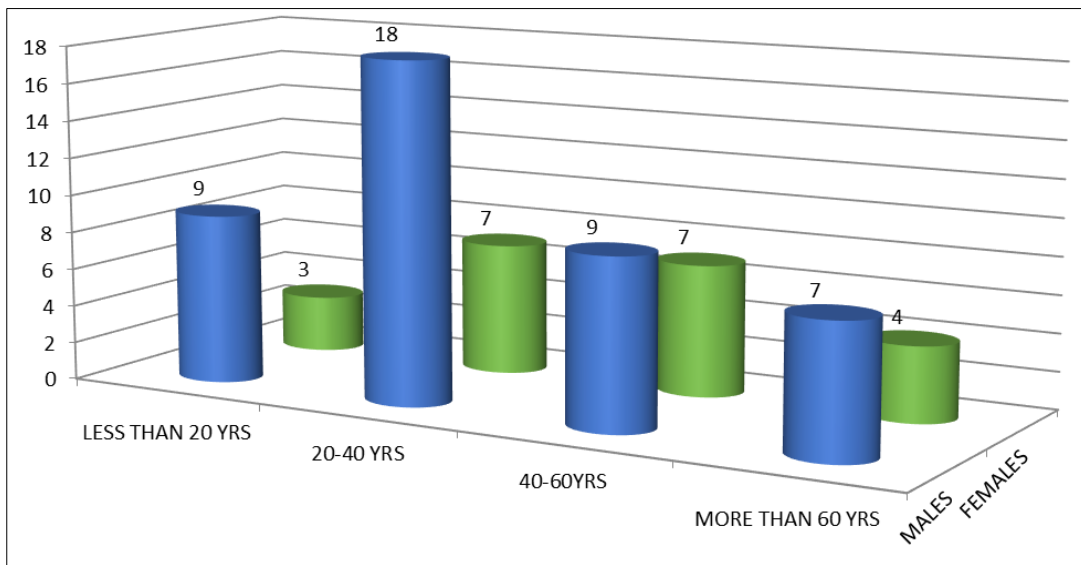


Fig 5: Represent the data of male and female patients in different age groups.

Selection Criteria

In this study following patients under inclusion and exclusion criteria, Data collected after completion of scan and reporting. Pediatrics, patients, any age and sex, All IPD and OPD patients were taken under inclusion criteria. Obese patients having weight more than acceptable limits, Claustrophobic, Recent Trauma, Post-Operative, Unwilling patients were taken under as exclusion criteria.

Data Analysis

Mean values, Correlation of signal intensities of white matter on T2W and FLAIR sequences and grey, the matter was seen individually as shown in figure 6 & 7. For the linear correlation as per age group with signal intensities on T2W & FLAIR, Karl Pearson's Correlation and one-way ANOVA methods applied through SPSS version 21.0.

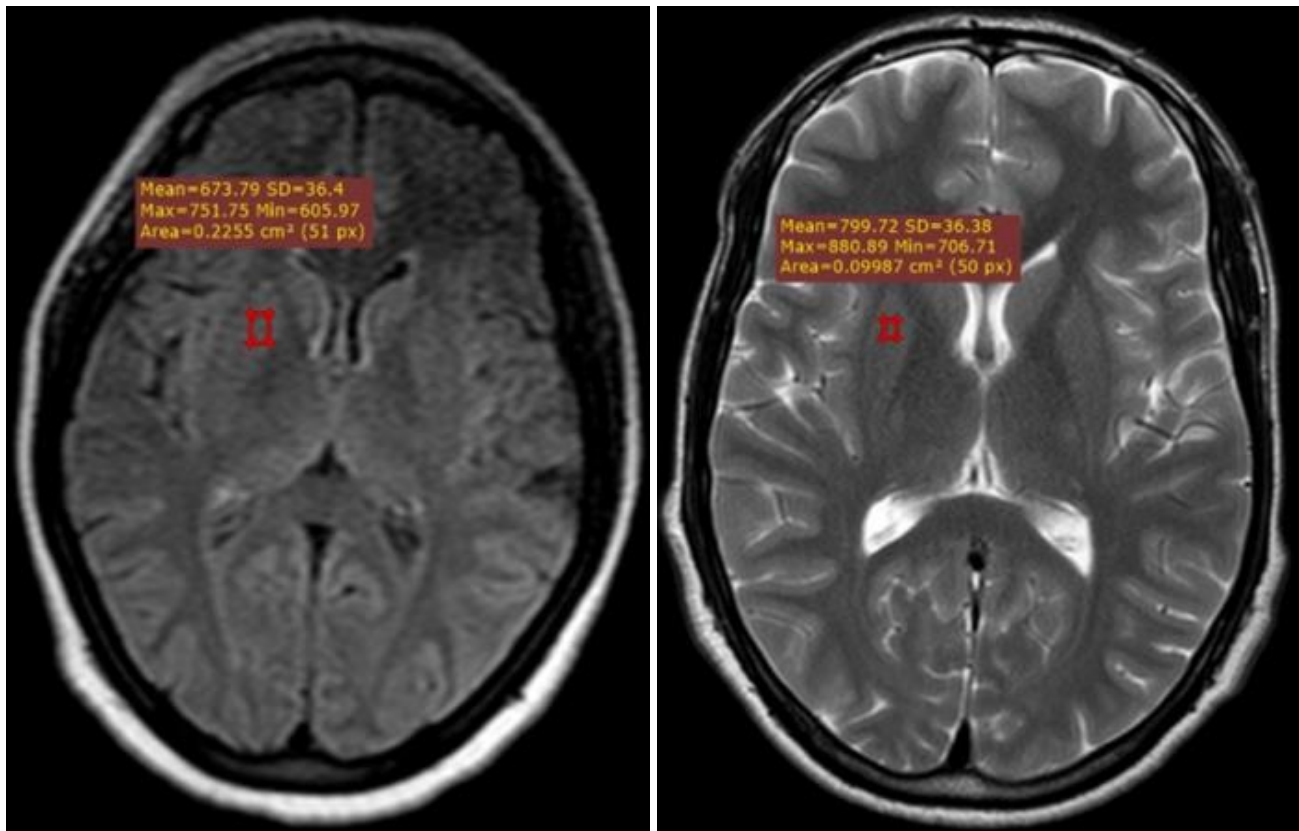


Fig 6 & 7: Shows measuring of Signal intensities on FLAIR and T2W sequences

Result

This study contains a total of 64 number of patients, which sub distributed in four different age groups, the different age groups are less than 20 years, 20 to 40 years, 40 to 60 years and more than 60 years of a group of patients. Each patient's Signal intensities of white matter and grey matter were calculated on T2W and FLAIR (Fluid Attenuated Inversion Recovery) sequences on the MRI console. Correlation of signal intensities of white matter on T2W and FLAIR sequences and grey matter were seen individually. For the linear correlation as per age group with signal intensities on T2W & FLAIR,

Karl Pearson's Correlation and one-way ANOVA methods applied through SPSS version 21.0.

Age group less than 20 years

A total of 12 patients were in this group in which male 75% and female 25% and the mean average of signal intensity of white matter on T2W is 926.1 and 922.2 on FLAIR and grey matter mean is 990.8 & 1027.3 on T2W & FLAIR respectively. Pearson correlation was found a significantly positive relationship in both white and grey matter i.e p=0.912 & p=0.944 respectively is shown below table no. 1 & 2.

Table 1: Shows the Karl Pearson's correlation of White matter in T2W & FLAIR sequences of MRI

Correlations White Matter			
		T2W Signal Intensities of less than 20 yr age group	FLAIR Signal Intensities of less than 20 yr age group
T2W Signal Intensities of less than 20 yr age group	Pearson Correlation	1	.912**
	Sig. (2-tailed)		.000
	N	12	12
FLAIR Signal Intensities of less than 20 yr age group	Pearson Correlation	.912**	1
	Sig. (2-tailed)	.000	
	N	12	12

** . Correlation is significant at the 0.01 level (2-tailed).

Table 2- Shows the Karl Pearson's correlation of Grey matter in T2W & FLAIR sequences of MRI.

Age group 20 to 40 years

A total of 25 patients were in this group in which male 72% and

female 28% and the mean average of signal intensity of white matter on T2W is 671.03 and 708.1 on FLAIR and grey matter mean is 826.3 & 877.0 on T2W & FLAIR respectively. Pearson correlation was found a significantly positive relationship in white matter p=0.290 and grey matter non-significant correlation were p=0.000 is shown below table no 3 & 4.

Table 3: Shows the Karl Pearson’s correlation of White matter in T2W & FLAIR sequences of MRI

Correlations White Matter			
		T2W Signal Intensities of Age Between 20 to 40 years	FLAIR Signal Intensities of Age Between 20 to 40 years
T2W Signal Intensities of Age Between 20 to 40 years	Pearson Correlation	1	.290
	Sig. (2-tailed)		.160
	N	25	25
FLAIR Signal Intensities of Age Between 20 to 40 years	Pearson Correlation	.290	1
	Sig. (2-tailed)	.160	
	N	25	25

Table 4: Shows the Karl Pearson’s correlation of Grey matter in T2W & FLAIR sequences of MRI.

Correlations Grey Matter			
		T2W1 Signal Intensities of Age Between 20 to 40 years	FLAIR1 Signal Intensities of Age Between 20 to 40 years
T2W1 Signal Intensities of Age Between 20 to 40 years	Pearson Correlation	1	.000
	Sig. (2-tailed)		.999
	N	25	25
FLAIR1 Signal Intensities of Age Between 20 to 40 years	Pearson Correlation	.000	1
	Sig. (2-tailed)	.999	
	N	25	25

Age group 40 to 60 years- A total of 16 patients were in this group in which male 57% and female 43% and the mean average of signal intensity of white matter on T2W is 754.1 and 727.9 on FLAIR and grey

matter mean is 891.8 & 870.1 on T2W & FLAIR respectively. Pearson correlation was found a significantly positive relationship in both white and grey matter i.e p=0.248 & p=0.158 respectively is shown below table no 5 & 6.

Table 5: Shows the Karl Pearson’s correlation of White matter in T2W & FLAIR sequences of MRI

Correlations White Matter			
		T2W Signal Intensities of 40 yr to 60 yr age group	FLAIR Signal Intensities of 40 yr to 60 yr age group
T2W Signal Intensities of 20 yr to 40 yr age group	Pearson Correlation	1	.248
	Sig. (2-tailed)		.355
	N	16	16
FLAIR Signal Intensities of 20 yr to 40 yr age group	Pearson Correlation	.248	1
	Sig. (2-tailed)	.355	
	N	16	16

Table 6: Shows the Karl Pearson’s correlation of Grey matter in T2W & FLAIR sequences of MRI

Correlations Grey Matter			
		T2W1 Signal Intensities of 40 yr to 60 yr age group	FLAIR1 Signal Intensities of 40 yr to 60 yr age group
T2W1 Signal Intensities of 20 yr to 40 yr age group	Pearson Correlation	1	.158
	Sig. (2-tailed)		.560
	N	16	16
FLAIR1 Signal Intensities of 20 yr to 40 yr age group	Pearson Correlation	.158	1
	Sig. (2-tailed)	.560	
	N	16	16

Age group more than 60 years

A total of 11 patients were in this group in which male 64% and female 36% and the mean average of signal intensity of white matter on T2W is 726.7 and 875.1 on FLAIR and grey matter

mean is 845.07 & 901.1 on T2W & FLAIR respectively. Pearson correlation was found a significantly positive relationship in both white and grey matter i.e. p=0.777 & p=0.761 respectively is shown below table 7 & 8.

Table 7: Shows the Karl Pearson’s correlation of White matter in T2W & FLAIR sequences of MRI

Correlations White Matter			
		T2W Signal Intensities of above 60 yr age group	FLAIR Signal Intensities of above 60 yr age group
T2W Signal Intensities of above 60 yr age	Pearson Correlation	1	.777**

group	Sig. (2-tailed)		.005
	N	11	11
FLAIR Signal Intensities of above 60 yr age group	Pearson Correlation	.777**	1
	Sig. (2-tailed)	.005	
	N	11	11

** . Correlation is significant at the 0.01 level (2-tailed).

Table 8: Shows the Karl Pearson’s correlation of Grey matter in T2W & FLAIR sequences of MRI

Correlations Grey Matter			
		T2W1 Signal Intensities of above 60 yr age group	FLAIR1 Signal Intensities of above 60 yr age group
T2W1 Signal Intensities of above 60 yr age group	Pearson Correlation	1	.761**
	Sig. (2-tailed)		.007
	N	11	11
FLAIR1 Signal Intensities of above 60 yr age group	Pearson Correlation	.761**	1
	Sig. (2-tailed)	.007	
	N	11	11

** . Correlation is significant at the 0.01 level (2-tailed).

One-way Anova were also found positive significant relationship, where age is dependent and signal intensities on T2W & FLAIR were independent, positive significant value p=

0.006 as shown in below table no 9. Age Dependent variable curve distribution of each signal intensities positive correlation curve shown in figure 8.

Table 9: Shows positive significance relationship (p=0.006), age is dependent variable and rest are constant variables

One- Way ANOVA ^a						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	6757.949	4	1689.487	4.038	.006 ^b
	Residual	24683.259	59	418.360		
	Total	31441.208	63			

a. Dependent Variable: Age

b. Predictors: (Constant), FLAIR1, T2W1, FLAIR, T2W

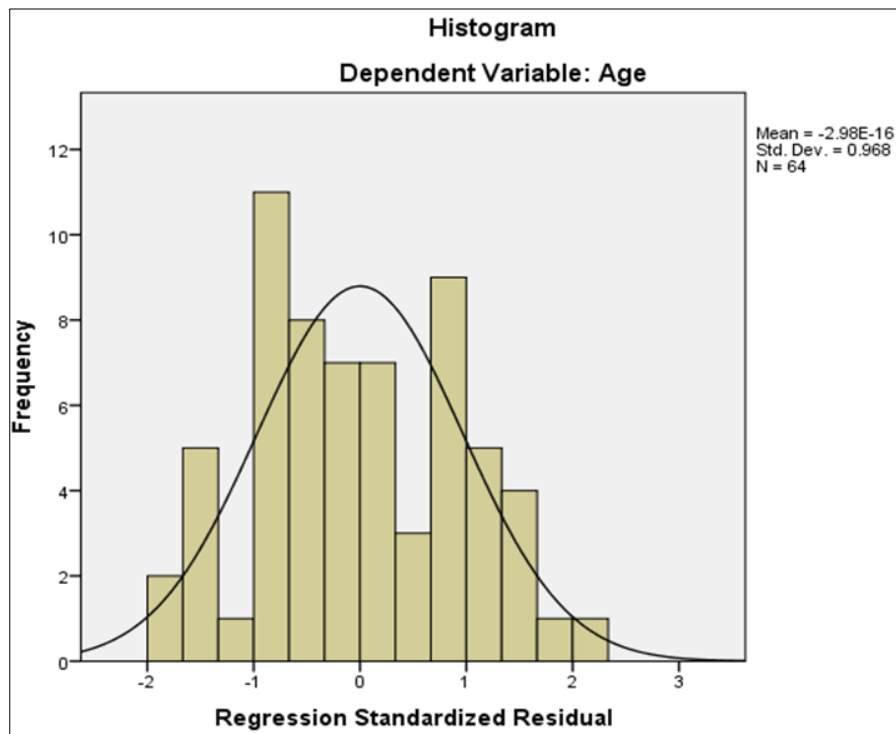


Fig 8: Histogram shows dependent variable curve distribution of each signal intensities positive correlation.

Discussion

In this study, compared the signal intensities of white matter and grey matter on T2W and FLAIR sequences of MRI Brain. The study is inspired by a research conducted on First Cut at Interpreting Brain MRI Signal Intensities: What’s White, What’s Black, and What’s Grey study by Parmar H. *et al* [4]. Most pathologic conditions of the brain and spinal cord parenchyma produce this combination of signal intensities, including cyst fluid, abscess, edema, encephalomalacia, demyelination, and necrosis. Normal cerebrospinal fluid (CSF) also have this combination of signal intensities. These tissues or lesions show black T1 and white T2 signal because they contain more water

than normal grey matter [4]. In this study values of signal intensity were measured manually to the white matter and grey matter areas on T2W and FLAIR sequences of MRI Brain. The Highest signal intensities (Figure- 9) & lowest signal intensities (Figure-10) values of white matter and grey matter on T2W & FLAIR are represents the different variations as per age. Areas like Corona Radiate for white matter fibers and caudate, Putamen, lenticular internal capsule and thalami for grey matter were selected to measure the signal intensities because no prone structures interfere in it and able to measure true values, no any prone structures and intensities like CSF, Fluid in it.

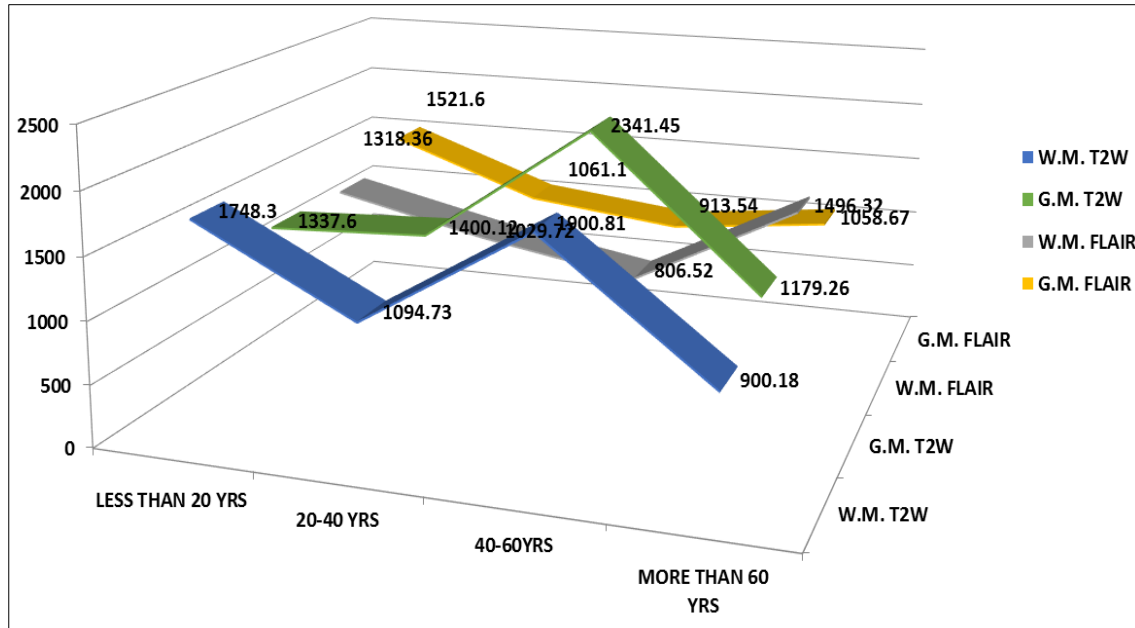


Fig 9: Represent the data of Highest Signal Intensity values of White Matter and Grey Matter on T2w and FLAIR axial sequences of MRI Brain.

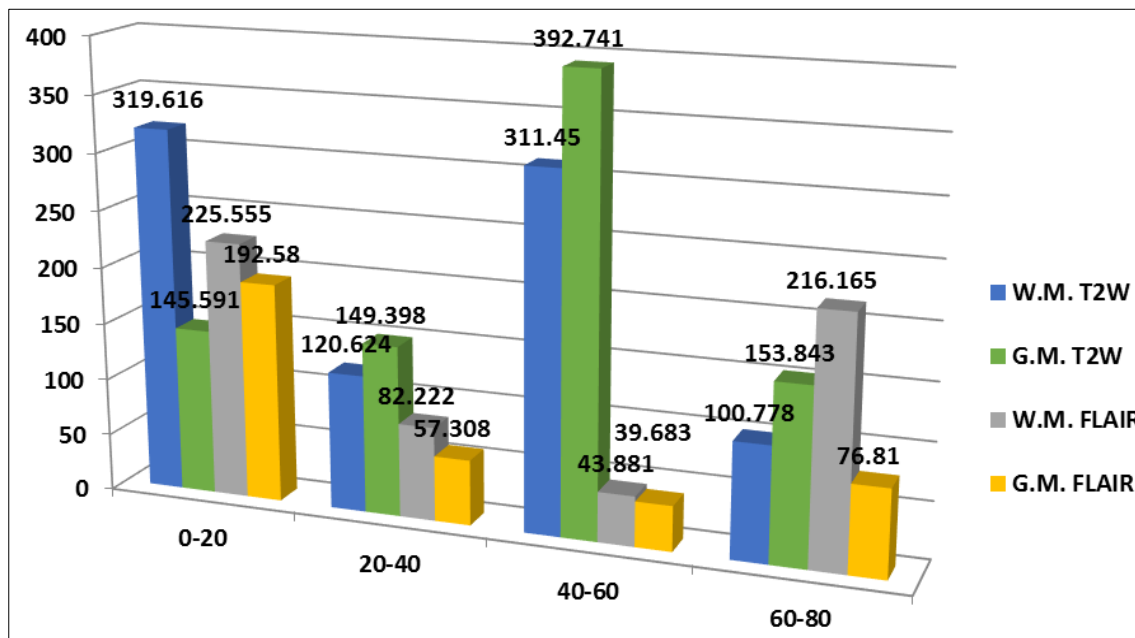


Fig 10: Represent the data of Lowest Signal Intensity values of White Matter and Grey Matter on T2w and FLAIR axial sequences of MRI Brain.

Conclusion

Study concluded that signal intensity values show variation with age and dependent on various pathologies. And hence signal intensity measurement may/can play an important role to rule out the proper diagnosis.

Contributors

All authors contributed to the conception or design of the work, the acquisition, analysis, or interpretation of the data. All authors were involved in drafting and commenting on the paper and have approved the final version.

Funding

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The author has no conflict of interest.

Disclosure

The author did not receive any type of commercial support in forms of either compensation or financial support for this study. Ethical approval & Informed consent was obtained from all participants.

References

1. Ansoorge R, Graves M. The physics and mathematics of MRI.
2. Hanson L. Is quantum mechanics necessary for understanding magnetic resonance? *Concepts Mag Reson Part A*. 2008; 32(5):329-40.
3. Weishaupt D, Köchli V, Marincek B. How does MRI work?. Berlin: Springer, 2008
4. Parmar H, Trobe J. A “First Cut” at Interpreting Brain MRI Signal Intensities: What’s White, What’s Black, and What’s Gray, *JNO*. 2010; 30(1):91-3.
5. Nazarpoor M, Poureisa M, Daghighi M. Comparison of Maximum Signal Intensity of Contrast Agent on T1-Weighted Images Using Spin Echo, Fast Spin Echo and Inversion Recovery Sequences. *ijr*. 2012;10(1):27-32
6. Ginat D, Meyers S. Intracranial Lesions with High Signal Intensity on T1-weighted MR Images: Differential Diagnosis. *Radio Graphics*. 2012; 32(2):499-516.
7. Kates R, Atkinson D, Brant-Zawadzki M. Fluid-attenuated Inversion Recovery (FLAIR). *Topics in Magnetic Resonance Imaging*. 1996; 8(6):389-96.
8. Saranathan M, Worters P, Rettmann D, Winegar B, Becker J. Physics for clinicians: Fluid-attenuated inversion recovery (FLAIR) and double inversion recovery (DIR) Imaging. *Journal of Magnetic Resonance Imaging*. 2017; 46(6):1590-1600.
9. Goehde S, Forsting M, Debatin J. Screening with MRI: A new “all inclusive” protocol. *Seminars in Ultrasound, CT and MRI*. 2015; 24(1):2-11.
10. Vézina L. MRI: Protocols to optimize lesion detection. *Epilepsia*. 2011; 52:25-27.
11. MS J. Assessing Multiple Sclerosis Brain Plaques using Susceptibility-Weighted Imaging in Comparison with T2W and FLAIR. *Clinical Radiology & Imaging Journal*, 2018, 2(2).
12. Masutani S, Tachibana T, Tomozawa K. 317 Evaluation of the fast-FLAIR sequence in head MRI. *Japanese Journal of Radiological Technology*. 1995; 51(10):1388.
13. Welker K, Patton A. Assessment of Normal Myelination with Magnetic Resonance Imaging. *Seminars in Neurology*, 2012; 32(01):015-028.
14. Haller S, Kövari E, Herrmann F, Cuvinciuc V, Tomm A, Zulian G, *et al*. Do brain T2/FLAIR white matter hyperintensities correspond to myelin loss in normal aging? A radiologic-neuropathologic correlation study. *ANPC*, 2013, 1(1).
15. Şasıadek M. Intracranial Lesions with Low Signal Intensity on T2-weighted MR Images – Review of Pathologies. *pjr*. 2015; 80:40-50.
16. Miller J, Hu H, Pokorney A, Cornejo P, Towbin R. *et al*. MRI Brain Signal Intensity Changes of a Child During the Course of 35 Gadolinium Contrast Examinations. *Pediatrics*. 2015; 136(6):e1637-40.
17. Wardlaw J, Valdés Hernández M, Muñoz-Maniega S. *et al*. What are White Matter Hyperintensities Made of?. *JAHA*, 2015, 4(6).
18. Zhong Y, Utraiainen D, Wang Y, Kang. Automated White Matter Hyperintensity Detection in Multiple Sclerosis Using 3D T2 FLAIR. *ijbi*. 2014; 2014:1-7.
19. Saake M, Schmidle A, Kopp M, Hanspach J, Hepp T, Laun F *et al*. MRI Brain Signal Intensity and Relaxation Times in Individuals with Prior Exposure to Gadobutrol. *Radiology*. 2019; 290(3):659-68.
20. Early myelination and high signal intensity on heavily T2 weighted Fluid Attenuated Inversion Recovery (FLAIR) sequences: evidence for primitive myelination?. *EHD*. 2019; 36(3):225-7