Original Article

Loss of Hippocampal Striations on 3.0 T MRI as an Effective Diagnostic Parameter for Mesial Temporal Sclerosis.

Imran Nazir Salroo , Reyaz Ahmad Mir, R. Emmanuel ,Musaddiq Rafiq Bhat.

Abstract

Background: Mesial Temporal Sclerosis, also known as MTS, is a condition that causes medial temporal lobe epilepsy (MTLE) and is characterized by the loss of hippocampal neurons. Multiple researches on individuals with hippocampal sclerosis (HS) have demonstrated that MRI (magnetic resonance imaging) is an exhaustive method for locating the EF (epileptogenic focus).

Aims & Objectives: To study Partial Loss of Hippocampal Striations (PLHS) as a diagnostic parameter using 3.0 Tesla MRI to increase the confidence of diagnosing Mesial Temporal Sclerosis (MTS).

Material & methods: This prospective research was performed in 55 patients who had undergone 3T (GE SIGNA HDX) brain imaging under epilepsy protocol that included T2 axial, coronal FLAIR and 3D SPGR hippocampal volume assessment in addition to high resolution T2 coronal imaging over a period of two years at Department of Radiodiagnoses and Imaging (DORAI), Bharat Scans, Chennai, India.

Results: The detection of abnormal signal intensity (SI) on FLAIR (fluid attenuated inversion-recovery) images had a sensitivity (Sn.) of 55 percent, specificity (Sp.) of 97 percent, & accuracy of 56 percent [right side (RS)] and Sn. of 35 percent, Sp. of 74 percent, & accuracy of 61 percent [left side (LS)] for the treatment of MTLE. The detection of PLHS on T2-weighted images had a Sn. of 81 percent, Sp. of 87 percent, & accuracy of 64 percent (RS) and a Sn. of 71 percent, Sp. of 81 percent, & accuracy of 64 percent (LS) for the treatment of MTLE.

Conclusion: PLHS is more Sn. and Sp, for the diagnosis of bilateral MTLE

JK-Practitioner2024;29(1):34-41

Introduction

MTS is a disease which causes MTLE. It is caused by the loss of hippocampal neuronal (HN)[1]. Multiple studies with people who have HS have exhibited that an MRI is a good way to find the EF (epileptogenic focus)[1].

T2-weighted images (WI) or FLAIR sequences as well as thin coronal segments parallel to the hippocampus are the better ways of showing HS. The above table 1 highlights the observation of increased SI on FLAIR sequences (FS) on RS for the diagnosis of MTS had Sn. of 55%, Sp. of 97%, NPV of 84%, & PPV of 88%, Kappa value and chi-square were statistically significant.

Hippocampus atrophy (HA) on T2-WI & FLAIR images is a strong indicator of MTS. Even though MRI has been presented to have a high Sn. and Sp. for finding HS, it is challenging to identify bilateral HS because MRI explanation varies depending on correlating the SI as well as volume of the structures of the hippocampal on brain (both sides) in relatively similar person2,3.

A 3.0-T MRI system improved “signal-to-noise ratio” means that the section thickness can be reduced while the image quality and imaging time are kept within acceptable parameters. High-resolution T2-WI with a thin section thickness at 3.0 T helps us learn more about the anatomy of the hippocampus, like the cornu ammonis (CA) & dentate gyrus (DG). This information could help researchers to gain knowledge more about HS4,5. In patients with MTLE, high-resolution T2-WI taken at 3.0 T did not frequently reveal a dark line in the hippocampus, according to the findings of this study.

Hence, it is hypothesized that a PLHS may be more accurate than the generally accepted MRI techniques for HS identification.

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Cite this article as

Salroo IN , Mir RA, Emmanuel R,Bhat MR.Loss of Hippocampal Striations on 3.0 T MRI as an Effective Diagnostic Parameter for Mesial Temporal Sclerosis. Pract2024;29(1):34-41.

Full length article available at **Jkpractitioner.com** one month after publication

Keywords

MTS, MTLE, PLHS, MRI, and Hippocampus

Table 1. Comparison of increased signal intensity on FLAIR sequences on RS with EEG/histopathology

		Right		Total
		Positive	Negative	
FLAIR	Positive	8	1	9
	Negative	7	39	46
Total		15	40	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.553	0.301- 0.752		
Sp.	0.975	0.871- 0.996		
NPV	0.848	0.718- 0.924		
PPV	0.889	0.565- 0.980		
Kappa	0.563		<0.001	Significant
Chi-square	20.670		<0.001	Significant

A	SE (a)	AS (b)	Asymptotic 95 percent CI	
			LB	UB
0.754	0.086	0.004	0.586	0.922

Table 2. Comparison of increased SI on FLAIR sequences on LS with EEG/Histopathology

		Left		Total
		Positive	Negative	
FLAIR	Positive	10	7	17
	Negative	18	20	38
Total		28	27	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.357	0.207- 0.542		
Sp.	0.741	0.553- 0.868		
NPV	0.526	0.373- 0.675		
PPV	0.588	0.360- 0.784		
Kappa	0.617		0.432	Not significant
Chi-square	0.210		0.432	Not significant

Area	SE (a)	AS (b)	Asymptotic 95 percent CI	
			LB	UB
0.549	0.078	0.533	0.396	0.702

The above table highlights the observation of PLHS on T2-WI on right side for the diagnosis of MTS had Sn. of 80%, Sp. of 87%, NPV of 92%, & PPV of 70%. Kappa value and chi-square were statistically significant.

The focus of this research is to find out if PLHS at 3.0 T is a better way to find HS in people with MTLS than the commonly agreed techniques of implementing conventional MRI.

Table 3. Comparison of Loss of Hippocampal Striations on T2-WI on RS with EEG/histopathology

		Right		Total
		Positive	Negative	
PLHS	Positive	12	5	17
	Negative	3	35	38
Total		15	40	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.800	0.548- 0.930		
Sp.	0.875	0.739- 0.945		
NPV	0.921	0.792- 0.973		
PPV	0.706	0.469- 0.867		
Kappa	0.648		<0.001	Significant
Chi-square	23.275		<0.001	Significant

Area	SE (a)	AS (b)	Asymptotic 95 percent CI	
			LB	UB
0.838	0.068	0.000	0.705	0.970

Table 4. Comparison of Loss of Hippocampal Striations on T2- weighted images on left side with EEG/histopathology

		Left		Total
		Positive	Negative	
PLHS	Positive	20	5	25
	Negative	8	22	30
Total		28	27	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.714	0.529- 0.847		
Sp.	0.815	0.633- 0.918		
NPV	0.733	0.566- 0.858		
PPV	0.800	0.609- 0.911		
Kappa	0.648		<0.001	Significant
Chi-square	15.520		<0.001	Significant

Area	SE (a)	AS (b)	Asymptotic 95 percent CI	
			LB	UB
0.765	0.067	0.001	0.634	0.895

The above table highlights the observation of partial loss of hippocampal striations on T2-weighted images on left side for the diagnosis of MTS had Sn. of 71%, Sp. of 81%, NPV of 73%, & PPV of 80%. Kappa value and chi-square were statistically significant.

Materials & Methods

Patient and subjects

Prospective study was done in 55 patients who had undergone 3T (GE SIGNA HDX) brain imaging under epilepsy protocol that included T2 axial, coronal FLAIR and 3D SPGR hippocampal volume assessment in addition to high resolution T2 coronal imaging for the time frame of 2 yrs. Brain MRI evaluations were performed on 150 patients suspected of having epilepsy through our standard epilepsy brain MRI technique.

We chose 150 of these patients based on the following criteria.

Inclusion criteria

(a) People diagnosed clinically and electroencephalographic (EEG) with MTS.

(b) People who had never had surgery.
(c) People who didn't have any "extrahippocampal focal leptogenic lesions" could be seen on all of the MRI images.

In this research, the diagnosis of MTS was made by one highly specialized neurologist based on both medical as well as EEG observations (PS with twenty yrs. of expertise). In order to meet the criteria for a diagnosis, a patient had to have a history of either simple partial seizures (PS) or complicated PS, or both, as well as symptoms consistent with a MTL origin (increasing epigastric sensation, anxiety, experience-based phenomena, & autonomic symptoms & signs), and no other indication of a partial epilepsy disorder. Interictal epileptiform discharges observed on the EEG were required to fulfill the conditions.

Criteria for exclusion

Seizure semiology as well as EEG observations that indicate LTLE (lateral temporal lobe epilepsy) that is interictal EEG epileptiform anomalies and visual or auditory auras in the posterior temporal areas. As a result, ninety-five patients out of a total of 150 were exempted from the category of those with MTLE for the below reasons:

- Had NTLE (neocortical temporal lobe epilepsy) (n _ 4)
- TLE (Temporal lobe epilepsy) instead of NTLE/MTLE (n_12)
- Epilepsy related to Occipital or frontal lobe (n _ 33)
- Tumor in the brain (n _ 7)
- Cortical dysplasia (n _ 4)
- Contusion in the brain (n _ 3)
- Infarction in the Brain (n _ 4)
- Posterior reversible encephalopathy condition (n _ 3)
- Vascular deformity (n _ 1)
- Hypoxic encephalopathy (n _ 1)
- Progressive multifocal leukoencephalopathy (n _ 1)
- Lactic acidosis, encephalopathy, mitochondrial myopathy, as well as stroke such as episodes/MELAS disorder (n _ 1)
- Nonepileptic loss of consciousness (n _ 15)
- Cases related to post-operative situations (n _ 5).
- Tuberous sclerosis (n _ 1)

Thereby, the research population involved fifty-five patients, thirty-four with unilateral MTLE and four with bilateral MTLE (twenty-five in the left & seventeen in the right).

55 cases studied, there was a more or less equal distribution of cases in both sexes, with males slightly outnumbering females. 58 percent of the population sample consisted of males, while 42 percent consisted of females.

The number of people (Age between 2 to 76 yrs.; mean age - 39.0 yrs.) consisted of thirty-two male patients (Age between 3 to 76 yrs.; mean age - 39.0 yrs.) as well as twenty-three female patients (Age between 2 to 65 yrs.; mean age, 33.5 yrs.). After amygdalohippocampectomy or temporal lobectomy, thirty-eight of fifty-five MTLE foci were pathologically proven to be HS.

MRI Imaging

With the MR system "3.0-T (GE SIGNA HDX)" and a dedicated coil "HNS FP by GE", research were performed (posterior head horseshoe). The oblique coronal sequencing of T2-WI and FLAIR imaging were performed parallel to the hippocampi as key component of a standard research procedure. The brain MRI procedure for epilepsy also comprised an oblique axial FLAIR sequencing (parallel to the hippocampi), an axial T2-weighted fast spin-echo (S-E) sequencing, as well as an axial 3-D fast spoiled gradient-echo (G-E) sequencing.

Interpretation of an Image

1. Quantitative Evaluation: On T2-weighted MRI, one radiologist assessed the volume as well as thicknesses of the hippocampus (CA with eight yrs. of expertise).
2. Blinded Visual Assessment: The T2-weighted as well as FLAIR MRI were individually evaluated by 2 board-certified radiologists (M P., with twenty-three yrs. of expertise, and CA. with eight yrs. of expertise) who didn't participate in image manipulation. Hippocampal atrophy (HA) was measured as follows using T2-WI.

'0' Score	"Absent"
'1' Score	"Possibly Present" (Though no definitive diagnosis has been made)
'2' Score	"Probably Present"
'3' Score	"Definitely Present"

T2-WI & FLAIR images utilised the relatively similar scale to measure how solid an abnormal signal was in the hippocampus. The 2 radiologists also looked at T2-WI to see if there was PLHS in the hippocampus. This was given a positive (+ve) or negative (-ve) score. A disarray of the hippocampal body's longitudinal axis can be seen in any subject, as more than two-thirds of the striations weren't clearly described in 2 or more cross-sections via the hippocampal body. Consensus was reached after the radiologists conducted their own independent evaluations of the results.

Statistical Analysis

People with MTLE were looked at in terms of their absolute thickness as well as volume. For empirical visual evaluations, the MR observations were used to figure out the Sn., Sp., as well as accuracy (PLHS, atrophy, & abnormal SI in the hippocampus). Though other events were classified as "false-positive events (FPE)" in order to determine atrophy and abnormal SI, images with MTLE were shown to analyse "true-positive events (TPE)" in order to assess "MTLE probably present." A statistically significant distinction was supposed to exist when the 'P' value was below .001. The weighted kappa value (KV) was used to determine the interobserver inconsistency. The agreement strength was considered appropriate for KV

between 0.21 & 0.40, moderate for KV between 0.41 & 0.60, and excellent for KV greater than 0.61. Ta

Demographic Data

Bharat Scans' Department of Radiodiagnosis and Imaging in Chennai, India, evaluated 55 patients who had symptoms that indicated they may have epilepsy over the course of 2 years. For epilepsy-related brain MRI imaging, the standard protocol was conducted. Pearson's Chi-square and McNamer tests were used to evaluate continuous and categorical information, respectively, using the mean as well as standard deviation. It was found that a P value of less than 0.05 was statistically important. SPSS version 14.0 was used to look at the data that had been collected.

Results

Quantitative Assessment

Whenever the volume variation between the hippocampus as well as the other side was greater than ten percent, the hippocampus was regarded considerably smaller.

Blinded Visual Assessment

Table 5. Comparison of HA on RS with EEG/Histopathology

		Right		Total
		Positive	Negative	
Atrophy	Positive	8	1	9
	Negative	7	39	46
Total		15	40	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.533	0.310-0.752		
Sp.	0.975	0.871- 0.996		
NPV	0.848	0.718- 0.924		
PPV	0.889	0.565- 0.980		
Kappa	0.581		<0.001	Significant
Chi-square	20.597		<0.001	Significant

The above table highlights the observation of HA on RS for the diagnosis of MTLS had Sn. of 53%, Sp. of 97%, PPV of 88%, & Negative predictive value of 84%. Kappa and chi-square were statistically significant.

The findings of HA for the identification of MTLS had Sn. of 53%, Sp. of 97%, & accuracy of 58% (RS) and Sn. of 92%, Sp. of 40%, & accuracy of 33% (LS). The findings of abnormal SI on FLAIR images had a Sn. of 55%, Sp. of 97%, & accuracy of 56% (RS) and Sn. of 35%, Sp. of 74%, & accuracy of 61% (LS) for the identification of MTLE. The findings of PLHS on T2-WI had a Sn. of 80%, Sp. of 87%, & accuracy of 64% (RS) and Sn. of 71%, Sp. of 81%, & accuracy of 64% (LS) for the identification of MTLE. For T2-WI, the Sn. of 80% (RS) and 71% (LS) for PLHS observations was greater than those for HA (53% for right and 92% for left) as well as abnormal SI (55% for RS and 35% for LS). The KV for interobserver variations for PLHS on T2-WI was 0.64 (RS) as well as 0.64 (LS), indicating better interobserver agreement. On T2-WI, the KV was 0.58 (RS) & 0.33 (LS) for atrophy. The KV for FLAIR images with a high SI was 0.56 (RS) & 0.61 (LS).

Discussion

Bronen RA et al. 2 asserted that MTS is a structure of neuron cell loss in the hippocampus. Histological researches of hippocampi with HS have displayed that neuronal loss (NL) & gliosis happen most often in CA1, CA3, & CA46,7. Our quantitative analysis revealed that people with MTLS had a considerably smaller mean hippocampus volume. This pattern of atrophic of the hippocampal development in people with MTLE is similar to the way the hippocampal development looks in people with HS. The hippocampus volume differs from person to person.

Cheon et al.8 stated that that it was normal for some better and healthier people to have a difference of more than 10% between the sizes of the right and left hippocampi. Cook et al.9 proved that normal hippocampal volumes were very different and that there wasn't a simple linear correlation between this volume and the total volume of the brain. Such findings suggest that it is hard to ascertain whether HA is prevalent or not, especially in situations of bilateral HA. In MR volumetry, there was considerable overlap in MRI measurements between abnormal as well as normal hippocampi.

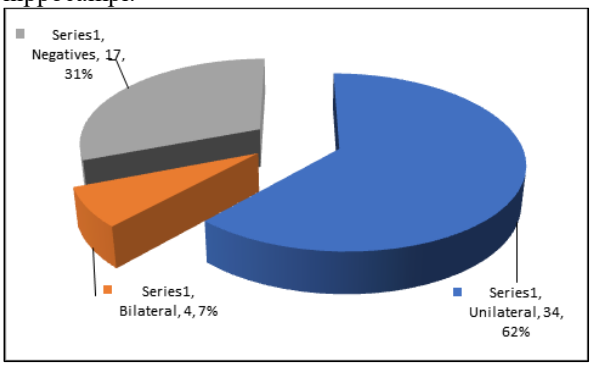


Figure 1. Total number of unilateral or bilateral cases of MTS including negative cases

Figure 1 demonstrates that out of the 38 positive cases of MTS detected as PLHS on T2-WI, 34 cases (61%) were unilateral, 4 cases (7.3%) were bilateral and 17 cases (31%) were negative.

It is known that thorough check of T2-WI or FLAIR images for unilateral HA and abnormal SI has a Sn. and Sp. of as high as 80 to 90 percent 10,11.

Table 6. Comparison of hippocampal atrophy and FLAIR sequence on both the sides of brain

Parameter	Estimate	95% CI
Hipocampal Atrophy on right side	0.754	0.586 – 0.922
Hipocampal Atrophy on left side	0.688	0.522- 0.814
Increased SI of RS of hippocampus on FLAIR sequence	0.752	0.484- 0.962
Increased SI of LS of hippocampus on FLAIR sequence	0.549	0.396- 0.702
PLHS on T2-WI on right side	0.838	0.705- 0.970
Partial loss of hippocampal striations on T2-weighted images on right side	0.765	0.634- 0.895

However, both the Sn. and Sp. in our research are relatively low than those in the earlier research.

The Figure 2 below show that more number of bilateral cases of MTS were diagnosed by detecting the PLHS on T2-WI than other parameters

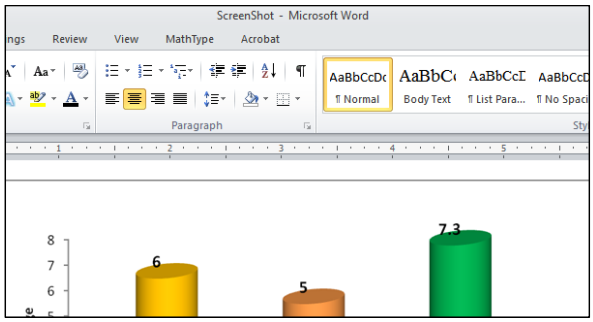


Figure 2. Total number of bilateral cases detected using parameters like HA, increased SI on FLAIR and PLHS on T2-WI

As of right now, 80–90% of patients with unilateral HA & abnormal SI on T2-WI or FLAIR images can be identified using visual inspection with this method10,11. Despite the fact that our study has a lower Sn. and Sp. than those found in earlier research.

In our research, the Sn. & Sp. of PLHS to identify MTS were respectively 80% (right), 71% (left), and 87% (right), 81% (left), which were considerably higher than some other criteria analyzed (HA & increased SI of hippocampus on FLAIR).

Table 7. Comparison of HA on LS with EEG/Histopathology

		Left		Total
		Positive	Negative	
Atrophy	Positive	26	16	42
	Negative	2	11	13
Total		28	27	55

Variables	Measures	95% CI	P VALUE	Statistically significant
Sn.	0.929	0.774- 0.980		
Sp.	0.407	0.245- 0.593		
NPV	0.846	0.578-0.957		
PPV	0.619	0.468-0.750		
Kappa	0.339		0.003	Significant at 5%
Chi-square	8.596		0.003	Significant at 1%

Area	SE (a)	AS (b)	Asymptotic 95 percent CI	
			LB	UB
0.668	0.074	0.033	0.522	0.814

The above table highlights the observation of HA left side for the diagnosis of MTLS had Sn. of 92%, Sp. of 40%, NPV of 84%, & PPV of 61%. Kappa value and chi-square were statistically significant at 5% and 1% respectively.

In addition, the interobserver agreement for PPLHS was greater than for abnormal as well as atrophy SI. Because of this, PLHS is much more specific & sensitive way to find bilateral MTLE than HA or abnormal SI because it doesn't depend on the relationship with the opposite hippocampus.

Wieshmann et al.12 evaluated MTS with high-spatial-resolution T2-WI at 1.5 T and 7.0 T. This revealed a number of dark lines, which were thought to represent, from outside to inside, the alveus, stratum moleculare & radiatum, as well as granular layer of the DG. In light of the research conducted by Wieshmann et al., we have made the presumption that the hippocampal striation that we analyzed for this research could possibly correlate to the stratum moleculare & radiatum.

According to Capizzano et al.4, when they used hippocampal data in connection with proton MR spectroscopy, sixty percent of cases of MTLE were lateralized. However, this percentage is lower than what we discovered with PLHS. In our research, the Sn. and Sp. of PLHS were 80% (right), 71% (left) and 87% (right), & 81% (left).

Jackson et al13 said that up to 15% of people with HS may have normal hippocampal volume (vol.) at MR imaging. The number of patients who have medical and EEG observations that are reliable with MTLE but in whom MRI shows no HA or SI abnormality has been given this by Cohen-Gadol et al 14. It was presumed that these patients had PTLE. In their study, the average loss of pyramidal cells in CA1 for PTLE was much less than for classic HS. Cohen-Gadol et al. talked about cases of PTLE, which may be the same as the cases of PLHS we discovered in our investigation.

Our research had a number of shortcomings: First, in some people, histologic affirmation of the diagnosis wasn't obtained. However, despite the fact that the clinical diagnosis for MTLE that we used were reliable & stringent15,16, they were primarily predicated on a clinical standard reference which involved EEG. Consequently, the meaning of negative & positive specimens without histologic clarification may affect Sn., Sp., & accuracy. The PLHS in MTLE appears to mainly portray the pathologic characteristics that are related to neuronal cell loss as well as the substitute of normal anatomic layers with gliotic tissue17.

The second limitation was the definition of PLHS. Although PLHS was described as the "non-visibility of more than two-thirds of the hippocampal striation in two or more cross-sections through the hippocampal body, a better definition of PLHS might exist." Thirdly, clear distinction between 1.5-T as well as 3-T MRI systems were not conducted.

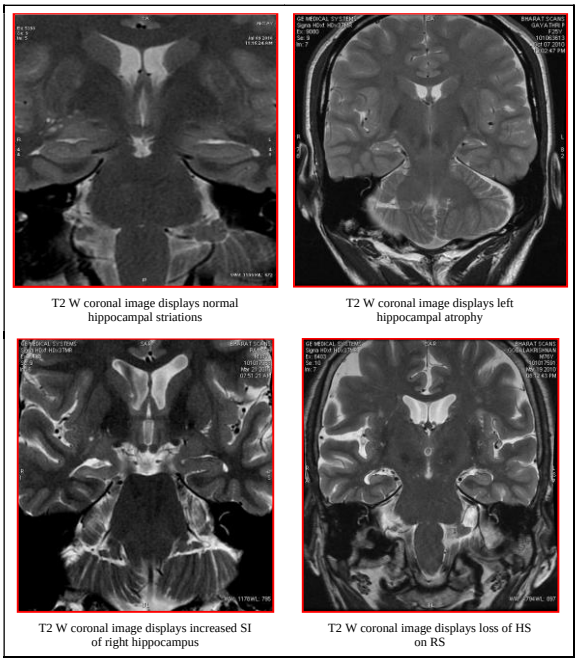
To summarize, PLHS in MTS is clearly visualized using 3T MRI, PLHS is the most frequent primary sign of MTS in MRI, PLHS is the principal sign in bilateral MTS with or without volume loss, in early MTS or MTS with normal volume (no atrophy). PLHS is the major primary sign with significant diagnostic accuracy. It does not require comparison with the contralateral hippocampus like other primary signs (volumetry or FLAIR hyperintensity).

It does not require post processing like volumetry. Also, it does not take long time like spectroscopy and T2 relaxometry having high sensitivity and specificity, interobserver variability is less.

Conclusion

1. PLHS in Mesial temporal sclerosis (MTS) is clearly visualized using 3Tesla MRI.

2. PLHS is the principal sign in bilateral Mesial Temporal Sclerosis (MTS) with or without volume loss.
3. In early MTS or MTS with normal volume (no atrophy), PLHS is the major primary sign with significant diagnostic accuracy.
4. PLHS does not require comparison with the contralateral hippocampus like other primary signs (volumetry or FLAIR hyperintensity).
5. PLHS is the most frequent primary sign of MTS in MRI.



T2 W coronal image displays normal hippocampal striations

T2 W coronal image displays left hippocampal atrophy

T2 W coronal image displays increased SI of right hippocampus

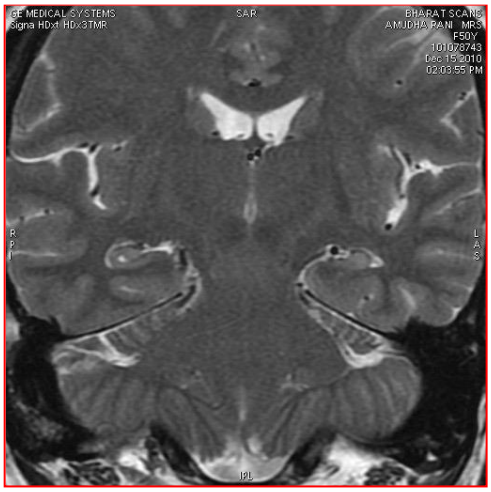
T2 W coronal image displays loss of HS on RS

T2 W coronal image displays normal hippocampal striations

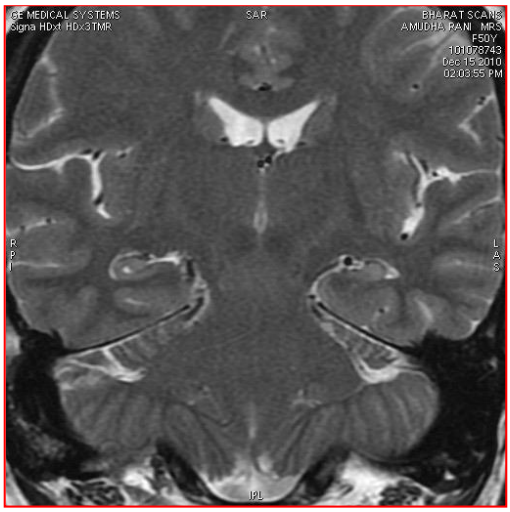
T2 W coronal image displays left hippocampal atrophy

T2 W coronal image displays increased SI of right hippocampus

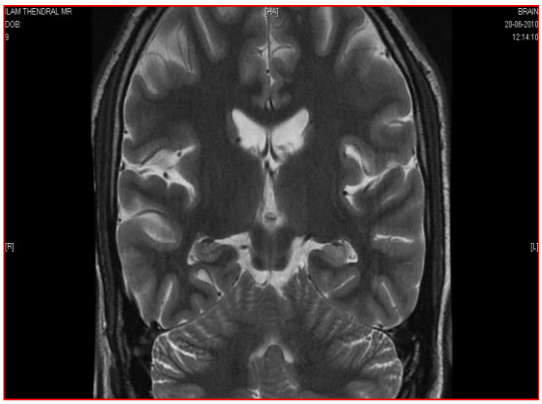
T2 W coronal image displays loss of HS on RS

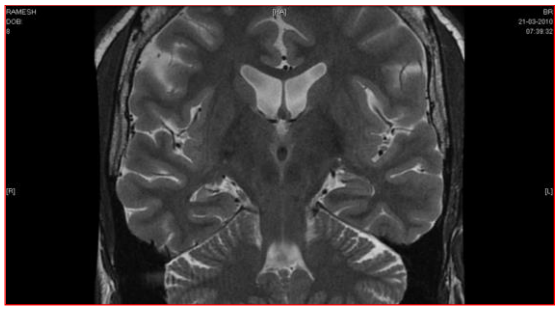


T2 W coronal image displays loss of HS on LS

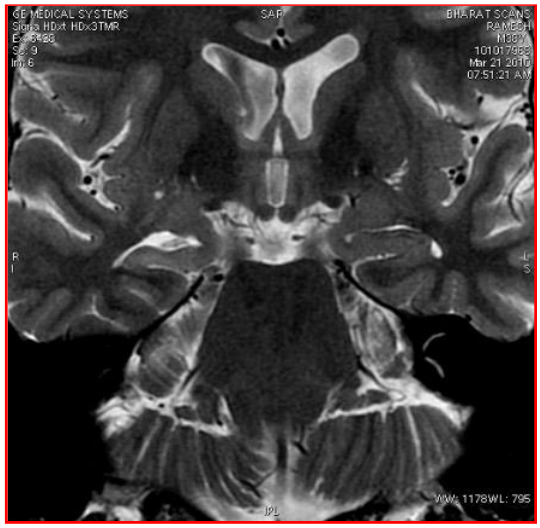


T2 W coronal image displays loss of HS in the left hippocampus body

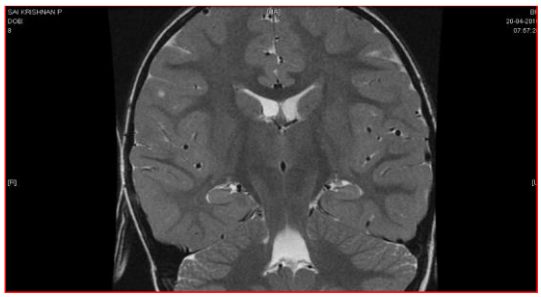




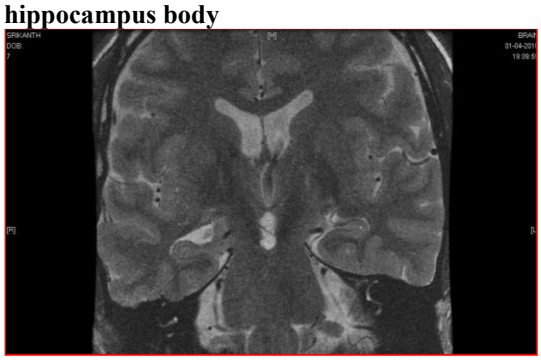
T2 W coronal image displays loss of HS on LS



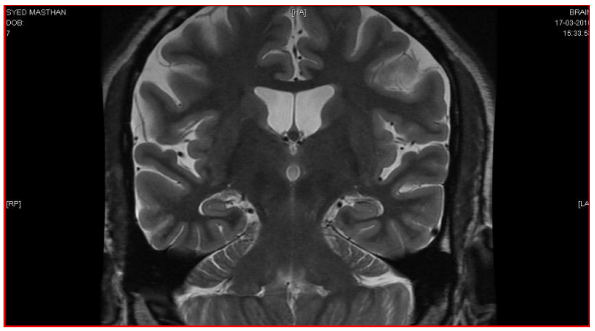
T2 W coronal image displays loss of HS in the left hippocampus body



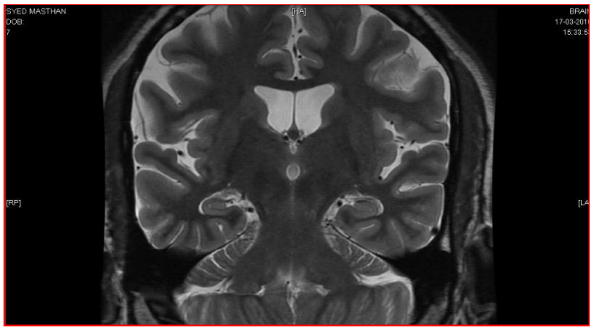
T2 W coronal image displays loss of HS in the left hippocampus body



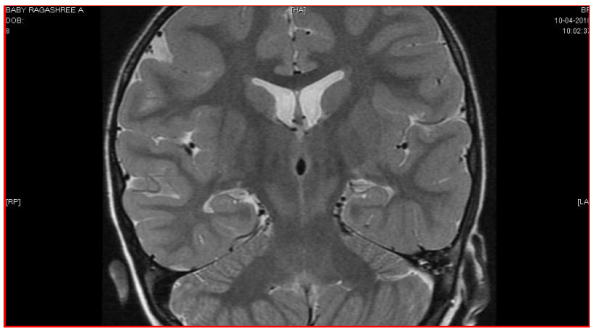
T2 W coronal image displays loss of HS in the left hippocampus body



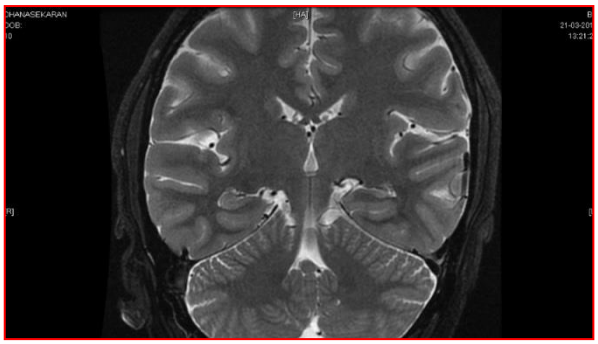
T2W coronal image displays small right hippocampus with loss of internal architecture & T2 hyperintensity



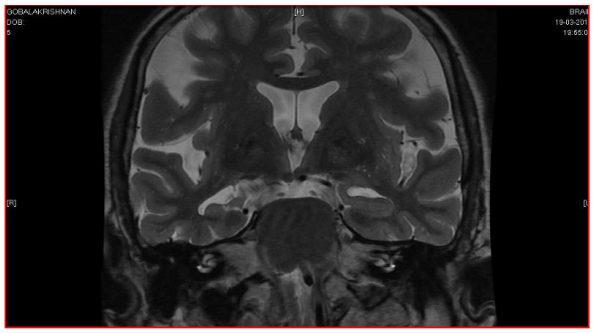
T2 W coronal image displays loss of HS in the body of left hippocampus



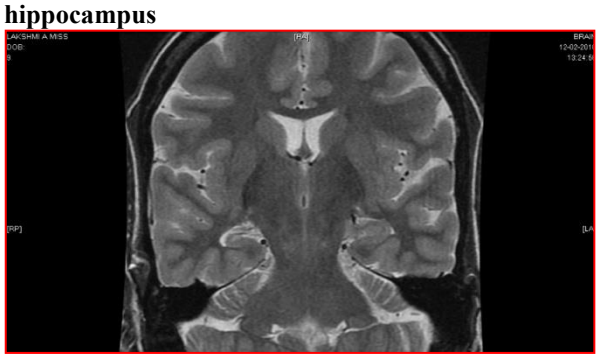
T2 W coronal image displays partial loss of HS in the left hippocampus



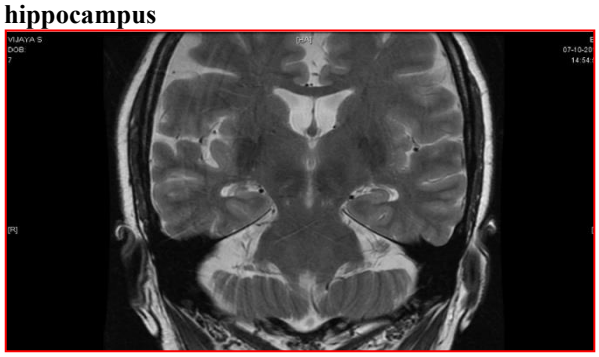
T2 W coronal image displays loss of HS in the left hippocampus



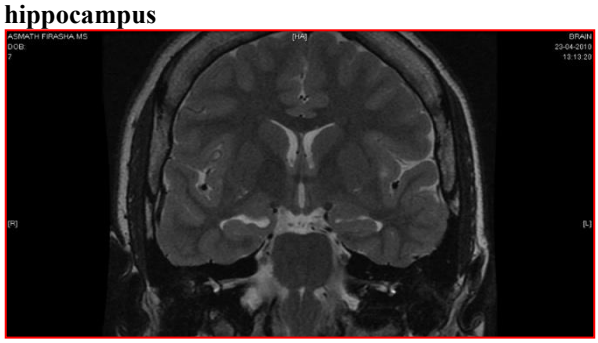
T2 W coronal image displays loss of HS in the right hippocampus



T2 W coronal image displays loss of HS in the right hippocampus



T2 W coronal image displays loss of HS in the right hippocampus



T2 W coronal image displays bilateral loss of HS

References

1. Hanamiya M, Korogi Y, Kakeda S, et al. Partial loss of hippocampal striation in medial temporal lobe epilepsy: pilot evaluation with high spatial resolution T2- weighted MR imaging at 3.0T.Radiology. Jun 2009;251:873-879.
2. Bronen RA, Fulbright RK, Spencer DD, et al. Refractory epilepsy: comparison of MR imaging, CT, and histopathologic findings in 117 patients. Radiology. Oct 1996;201(1):97-105.
3. Gibbs EL, Gibbs FA, Fuster B. Psychomotor epilepsy. Arch Neurol Psychiatry. 1948;60:331-339.
4. Capizzano AA, Vermathen P, Laxer KD, et al. Temporal lobe epilepsy: qualitative reading of 1H MR spectroscopic images for presurgical evaluation. Radiology. Jan 2001;218(1):51-144.
5. Bronen RA, Fulbright RK, Spencer DD, et al. Refractory epilepsy: comparison of MR imaging, CT, and histopathologic findings in 117 patients. Radiology. Oct 1996;201(1):97-105.
6. Babb TL, Leib JP, Brown WL, et al. Distribution of pyramidal cell density and hyperexcitability in the epileptic human hippocampal formation. Epilepsia. 1984;25:721-728.
7. Cascino GD, Jack CR Jr, Parisi JE, et al. Magnetic resonance imaging-based volume studies in t emporal lobe epilepsy: pathological correlations. Ann Neurol. 1991;30:31–36.
8. Cheon JE, Chang KH, Kim HD, et al. MR of Hippocampal Sclerosis: Comparison of Qualitative and Quantitative Assessments. AJNR Am J Neuroradiol. Mar 1998;19:465–468.
9. Cook MJ, Fish DR, Shorvon SD, et al. Hippocampal volumetric and morphometric studies in frontal and temporal lobe epilepsy. Brain. 1992;115: 1001–1015.
10. Jack CR Jr, Rydberg CH, Krecke KN, et al. Mesial temporal sclerosis: diagnosis with fluid-attenuated inversion-recovery versus spin-echo MR imaging. Radiology.1996;199:367–373.
11. Kim JH, Tien RD, Felsberg GJ, et al. Fast spin-echo MR in hippocampal sclerosis: correlation with pathology and surgery. AJNR Am J Neuroradiol. 1995;16:627–636.
12. Wieshmann UC, Symms MR, Mottershead JP, et al. Hippocampal layers on high resolutionmagnetic resonance images: real or imaginary? J Anat. 1999;195:131–135.
13. Jackson GD, Kuzniecky RI, Cascino GD, et al. Hippocampal sclerosis without detectable hippocampal atrophy. Neurology. 1994;44: 42–46.
14. Cohen-Gadol AA, Bradley CC, Williamson A, et al. Normal magnetic resonance imaging and medial temporal lobe epilepsy: the clinical syndrome of paradoxical temporal lobe epilepsy. J Neurosurg. 2005;102:902–909.
15. Kobayashi E, D'Agostino MD, Lopes-Cendes I, et al. Hippocampal atrophy and T2-weighted signal changes in familial mesial temporal lobe epilepsy. Neurology. 2003;60:405–409.
16. Labate A, Ventura P, Gambardella A, et al. MRI evidence of mesial temporal sclerosis in sporadic "benign" temporal lobe epilepsy. Neurology. 2006;66:562–565.
17. Kuzniecky R, Sayette V, Ethier R, et al. Magnetic resonance imaging in temporal lobe epilepsy: pathological correlations. Ann Neurol. 1987;22:341–347.