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The Application of Voxel Based Morphometery (VBM) on MRI in Temporal Lobe Epilepsy (TLE) Patients

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Abstract:-

Objective: The morphology and volume of the brain in TLE patients, especially hippocampus, amygdala, were displayed by cMRI scan, EEG and post-processing of 3D T1WI.

Methods: A total of 69 epileptic patients aged 18-60 years were collected for re-evaluation, including EEG, routine cMRI scan and 3D T1WI scan of the whole brain on 1.5T and 3.0T MRI. The 3D T1WI was further post-processed by VBM.

Results: In 1.5T MRI group, 30% were MRI negative. 20% showed the reduction of left hippocampal volume, 10% showed the reduction of right hippocampus, and 10% showed reduction of left amygdala, and consistent with the location of EEG. The right hippocampus showed a difference in the volume of patients with control group. In 3.0T MRI group, only 10% had TLE. In 3 cases of TLE, the volume of bilateral hippocampus in 33.33% patients was smaller than control and consistent with the location of EEG.

Conclusion: VBM combined with EEG and cMRI can provide detailed information for epileptics and helps in analysis of ROI structure, accurately measures and calculate the volumes.

Keywords:- *Epilepsy, Temporal Lobe Epilepsy (TLE), Conventional MRI (cMRI), Electroencephalography (EEG), Voxel Based Morphometry (VBM), Postprocessing, Region of interest (ROI).*

I. INTRODUCTION

Epilepsy is the most common neurological disorder affecting more than 0.07 billion people worldwide.[1] Among different types of epilepsy, temporal lobe epilepsy (TLE) is the most studied and common type of focal and drug-refractory epilepsy referred for epilepsy surgery and has a good prognosis for the surgery.[1,2-3] The diagnosis of epilepsy (depends on the clinical manifestation) mainly depends upon electroencephalography (EEG) combined with MRI, which is the most widely used modality. However, some patients have positive EEG but normal MRI (MRI negative) for epilepsy. MRI negative, which is the common problem encountered by radiologists, clinicians, and researchers, accounts for 9.3% of patients who underwent epilepsy surgery.[4-5]

Magnetic resonance imaging (MRI) of the brain is still considered as the golden standard radiological procedure to examine a patient because of its high resolution and detailed information as compared to other neuroimaging techniques to date. Ashburner and Friston first propose Voxel-based morphometry (VBM) in 2000.[6] It is the most popular algorithm which is commonly used till to the date.[7] It is based on the automated, comprehensive and objective analysis technology of voxel to brain structure MRI image, the density of brain tissue components can be quantitatively detected for the whole brain, to depict the characteristics of local brain areas and the differences of brain tissue components. The voxel-based MRI analysis appears to be a valuable additional diagnostic tool in the evaluation of patients with focal epilepsy, especially in patients with cortical abnormalities.[8]

In this study we postprocess T1-weighted (T1W) images and measure the volume of the brain in TLE patients, especially hippocampus, amygdala, were displayed by cMRI scan, EEG and post-processing of 3D T1WI.

II. MATERIALS AND METHODS

1. Clinical Data

From January 2018 to June 2021, In Second Affiliated Hospital of Guangzhou Medical University, Guangzhou, China, we evaluated 946 hospitalization patients to analyze the rate of positive and negative MRI epilepsy, age and sex (refer to **Table 2**) from picture archiving and communication system (PACS) of our hospital, who had diagnosed as epilepsy like symptoms through clinical examinations and had MRI in 1.5T and 3.0T MRI machines. All of these patients were admitted to our hospital and underwent MRI examination. The MRI images were analyzed by an experienced radiologist who is best in the neuroradiology of our hospital.

For the image post-processing the age range in this research was set as between 18 and 60 (including the boundary value). The reason the age range was set is that the Talairach space is not fully developed if age less than 18, and patients may have physiological atrophy if age more than 60.

In this research, the normality and abnormality when the images were acquired in the same modality with the same scanning parameters were compared, thus the main requirement of patient selection is without evident space-occupying effect and without any missing of the normal structures.

During this research, all the patients and the normal people underwent examinations with the approval of the institutional review board of our hospital. Written informed consent was obtained from patients, and normal people before enrollment, and all of them signed the informed consent form for the examination.

2. Equipments

1.5T MRI: General Electric (GE) HDx, made in the USA and Siemens Symphony, Germany.

3.0T MRI: MRI Philips Scanner (Philips Ingenia), made in Netherlands.

Windows operating system 10: To convert DICOM to NIFTI format

Linux operating system (Ubuntu): For further postprocessing of NIFTI Files

Freesurfer Software: version 3.05, a data processing software developed by MIT Health Sciences & Technology and Massachusetts General Hospital in the United States (US) (http://surfer.nmr.mgh.harvard.edu/).

SPSS: version 25.0.

FSL: http://www.fmrib.ox.ac.uk/fsl

The scanning parameters used in both 1.5T and 3.0T in this research were following the epilepsy standard operation protocols in our hospital, which includes the parameters for 3D T1W volumetric acquisition, T2WI, coronal T2-weighted fast spin-echo (FSE) in the whole brain, and FLAIR sequences with thin (2-3mm) slices perpendicular to the long axis of the hippocampus.

3. Methods

A total of 69 epileptic patients aged 18-60 years were collected for re-evaluation from 946 patients for postprocessing, 10 epileptic cases were randomly selected for 1.5T MRI examination group and compared with 9 normal controls, 59 epileptic cases for 3.0T MRI examination group and compared with 7 normal controls, both of them were processed in VBM. However, due to lack of sufficient data or missing data, 29 epilepsy cases in 3.0T MRI group were discarded, and eventually 30 epilepsy cases were used for this research. MRI groups composition please refer **Table 1**.

After the patient were scanned in both 1.5T and 3.0T MRI, T1WI was used for further postprocessing in VBM. T1WI provides high-resolution anatomical details and can be reformatted to any plane. MRI's DICOM files were transferred to the powerful computer for postprocessing. Windows 10 was used as operating system to convert DICOM files to NIFTI files by MRIConvert software and after that to change to Linux operating system (Ubuntu) to further postprocessing of NIFTI files and it was automatically processed by the FSL and

freesurfer. The data were analyzed by using a freeviewer and MATLAB in which the size and structure of the hippocampus, amygdala, and other brain structures were compared and analyzed by using the FSL and Freeview, and finally, the statistics were done. All the selected patients i.e., 40 patients (10 patients from 1.5T group and 30 patients from 3.0T group), underwent EEG examination in order to find the localization of the epileptic foci.

4.Statistical Analysis

SPSS version 25.0, IBM statistical software, was used for the statistical analysis and mathematical calculations. The independent-sample T-test was used to find the *P* values. The volumes of the left hippocampus, right hippocampus, left amygdala, and right amygdala in 1.5T and 3.0T were compared. *P* values less than 0.05 ($P < 0.05$) indicated statistical significance, which means there should be strong evidence against the null hypothesis, thus, we reject the null hypothesis and accept the alternative hypothesis. And a *P* values higher than 0.05 ($P > 0.05$) is not statistically significant and indicates strong evidence for the null hypothesis.

III. RESULTS

Among all the 946 patients from the PACS system of our hospital who had epilepsy like symptoms and had conducted an MRI, the lowest age was 5 months old, and the highest age was 89 years old, indicating that any age group can be affected from epilepsy. After performing MRI examinations, only 12 (1.27%) patients underwent surgery till to that date and due to lack of enough data we did not follow up the patients who had surgery. Summary of all these 946 patients please refer to **Table 2**. A total of 69 epileptic patients aged 18-60 years were collected for re-evaluation and further proceed for postprocessing.

1. 1.5T MRI Group

10 epileptic cases and 9 normal controls were randomly selected for 1.5T MRI group. In these 10 epileptic cases, 3 (3/10, 30%) cases were MRI negative, 7 (7/10, 70%) cases were MRI positive, along with 2 (20%) cases which were diagnosed as TLE.

From the data of 10 epileptic cases showing in **Table 3**, 3 cases were MRI negative, which is contradicts with the diagnose, respectively are case number E1, E2 and E3. But the VBM volume of the left hippocampus of case number E3 is obviously decreased as compare to right side.

From the VBM volume of case number E2, the size of both side hippocampus was found smaller than normal control. The measurement for 9 normal controls see **Table 4**. These indicated that there is abnormality in hippocampus, which can be a supportment data for the diagnose. The VBM volume of 3 MRI positive cases which case number is E5, E6, E9, showed the reduction of left amygdala, right hippocampal and left hippocampal volume, respectively, which was consistent with the location of EEG. The VBM analysis result, which contained the mean±standard deviation (SD) volume (in mm^3) and *P* values for 10 epileptic cases and 9 normal controls in 1.5T MRI group see **Table 5**.

The VBM analysis result shows that only the volumes of right hippocampus ($P = 0.031$; $P < 0.05$) has a significant difference between epileptic patients and normal people in 1.5T MRI group, no difference was found in left hippocampus and both sides amygdala. Which may indicated compare to normal controls, the abnormality more probably found in the right hippocampus.

2. 3.0T MRI Group

30 epileptic cases and 7 normal controls were randomly selected for 3.0T MRI group. Out of 30 patients, only 3 (10%) patients had TLE (case number E4, E10, E19), and other 27 (90%) patients had other epilepsy or epilepsy like symptoms such as generalized tonic-clonic seizure (GTCS), secondarily generalized tonic-clonic seizure (sGTCS), complex partial seizure (CPS), and simple partial seizure (SPS) as shown in **Table 6**.

The measurement in 3.0T MRI for 30 epileptic cases see **Table 7**. The measurement result shows that out of 3 TLE patients, 1 patient (case number E4) have bilateral decreased volume in the hippocampus as compared to normal controls; however, 2 patients (case number E10 and E19) show no difference in volume.

Besides, compare to normal controls, the measurement for 7 normal controls see Table 8; decreased volume in the hippocampus was found in case number E6, E11, E14, E16, E18, E24, E25 and E30, and decreased volume was found in left amygdala in case E2, E24 and E25 as well. These findings may also indicated compare to normal controls, the abnormality more probability found in the hippocampus.

The VBM analysis result, which contained the mean±standard deviation (SD) volume (in mm^3) and *P* values of 30 epileptic cases and 7 normal controls in 3.0T MRI group see **Table 9**. The VBM analysis result shows that there was no difference in the volumes of both sides hippocampus and amygdala between epileptic patients and normal controls in 3.0T MRI group, which is inconsistent with the data showing in **Table 7**, which indicated that compare the VBM volume of epileptic cases individually with normal controls instead of comparing the *P* value between them can provide better result and more reliable.

IV. DISCUSSION

In this study, a considerable number of patients, i.e., 946 patients who were hospitalized in our hospital from January 2018 to June 2021 and diagnosed as epilepsy by clinical history (primarily neurological), EEG and MRI (1.5T and 3.0T), were analyzed to determine the epilepsy rate. The minimum age who had admitted to our hospital and diagnosed as epilepsy and had MRI examination was 5 months old, and the maximum age was 89 years old, any age group can be affected by epilepsy. Among these cases, there were 563 (563/946, 59.51%) males and 383 (383/946, 40.49%) females, data shows that males are affected more than females. Among 946 epileptic patients, 623 (65.86%) had positive findings on MRI, while 323 (34.14%) had MRI negative. It is reported that MRI negative was only seen in about 33% of patients and 66% of MRI positive, whereas, the true ratio of MRI negative in the general population is unknown.[9]

For the research purpose, 10 epileptic patients with 9 normal controls were enrolled in 1.5T MRI group and 30 epileptic patients with 7 normal controls in 3.0T MRI group.

In 1.5T MRI group, 3 (3/10, 30%) epileptic patients were MRI negative, and 7 (7/10, 70%) epileptic patients were MRI positive. The 3 MRI negative cases in Table 3 (case number E1, E2, E3) was contradicts with the diagnose. But from the VBM volume of the 3 MRI negative cases, we can see that, for case number E3, the left hippocampus is obviously decreased as compare to right side one; for case number E2, the size of both side hippocampus was smaller than normal control. These VBM volume abnormality in hippocampus is consistent with the diagnose. The VBM volume of 3 MRI positive cases which case number is E5, E6, E9, showed the reduction of hippocampal volume, which was consistent with the location of EEG.

On the other hand, in 3.0T MRI group, only 3 (3/30, 10%) patients had TLE, and the other 27 (27/30, 90%) patients had other epilepsy. The measurement (see Table 7) result show that out of 3 TLE patients, 1 patient (case number E4) have bilateral decreased volume in the hippocampus as compared to normal controls; however, 2 patients (case number E10 and E19) show no difference in volume. Besides, decreased volume in the hippocampus was found in case number E6, E11, E14, E16, E18, E24, E25 and E30, and in left amygdala in case E2, E24 and E25 as well. These findings may also indicated compare to normal controls, the abnormality more probability found in the hippocampus.

VBM is more accurate for the measurement of adult hippocampal volume and hippocampus related clinical diseases than freesurfer software. It is also found that, in both adult and elderly patients, the right side hippocampus is larger than the left side.[10] In this study, all normal cases, and most of the epileptic patients, the right side of hippocampus and amygdala are more prominent than the left. Only 1 case was found having smaller hippocampus sizes on the right side than left side in each MRI group, respectively case number E6 in 1.5T MRI group (1/10, 10%) and case number E18 in 3.0T MRI group (1/30, 3.33%). In the volumetric analysis, about 90% of TLE patients with HS had significant hippocampal atrophy, and about 20% had significant ipsilateral amygdala atrophy.[11] While on the other hand, volumetric studies on MRI negative TLE, there is significant amygdala enlargement in 14-16% of patients. [12,13]

VBM in patients with mTLE shows atrophy of putamen, pallidum, middle and inferior temporal gyri, amygdala, and cerebellar hemispheres.[14] VBM in TLE patients found that GM abnormalities were evident in the ipsilateral hippocampus and ipsilateral thalamus whereas, temporal and extratemporal WM was affected ipsilateral to the side of seizure onset.[15] In the elderly patients with TLE, VBM shows significant GM volume increases in the bilateral amygdala and anterior hippocampus.[16] In VBM analysis, it is found that there are significant ipsilateral mesiotemporal GM and WM volume reductions in TLE-HS patients. In our study, it was found that in 1.5T MRI group, the right hippocampus ($P = 0.031$; $P < 0.05$) showed that there was a difference in the volumes of epileptic patients and normal people. However, P value of the left amygdala, right amygdala, and left hippocampus showed no difference in the volumes in 1.5T MRI group. In 3.0T MRI group, the P value of the left amygdala, right amygdala, left hippocampus, and right hippocampus showed no difference in the volumes.

There is no significant difference when scanning from both 1.5T and 3.0T MRI in epileptic patients. In TLE patients when measuring individually with normal control, the size of hippocampus and amygdala is smaller in epileptic patients in which epileptic foci by EEG lies.

V. LIMITATIONS

The limitation of this research is less or limited number of patients with complete clinical combination. Due to the small sample size while comparing the normal cases with epileptic cases in group, we could not find any significant difference. However, when compare individually it finds the significant difference between normal and epileptic patients. Unlike other cMRI examinations in epilepsy, this VBM study consumes more time for postprocessing. Also, there is a limited number of works of literature about VBM in TLE with clinical correlation, so we cannot compare the accuracy and diagnostic sensitivity of our study with others.

VI. CONCLUSIONS

The post-processing of VBM using 1.5T and 3.0T cMRI's T1WI is key to the detailed volumetric measurement of the brain structures. VBM combine with EEG provides more detailed information about TLE patients. EEG gives the localization and provides the information of the epileptic foci whereas, VBM provides the volumetric measurement of those structures. Meanwhile, VBM also provides the analysis of the ROI structures and specific measures and calculates the volume and helps to find abnormalities. The VBM based cMRI analysis appears to be a valuable additional diagnostic tool in the evaluation of patients with symptomatic or unknown origin TLE. The cMRI with VBM can solve more problems in the localization, quantification, and qualification of epileptic foci combining with clinical symptoms and EEG. In VBM, when analyzing epileptic patients with guided EEG, the key for this research is to compare the cases individually with normal controls instead of comparing the *P* value, which can provide better result and more reliable. VBM analysis can be an assistant tool to help diagnose epileptic while the cMRI result is inconsistent with the EEG findings.

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Footnotes

Authors' Contribution: Nitesh Shrestha conducted the study concept and design. Hou Zhongjun analyzed and wrote the primary draft of the manuscript. Both authors contributed to the revision of the manuscript, read, and approved the final version.

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FIGURE LEGENDS

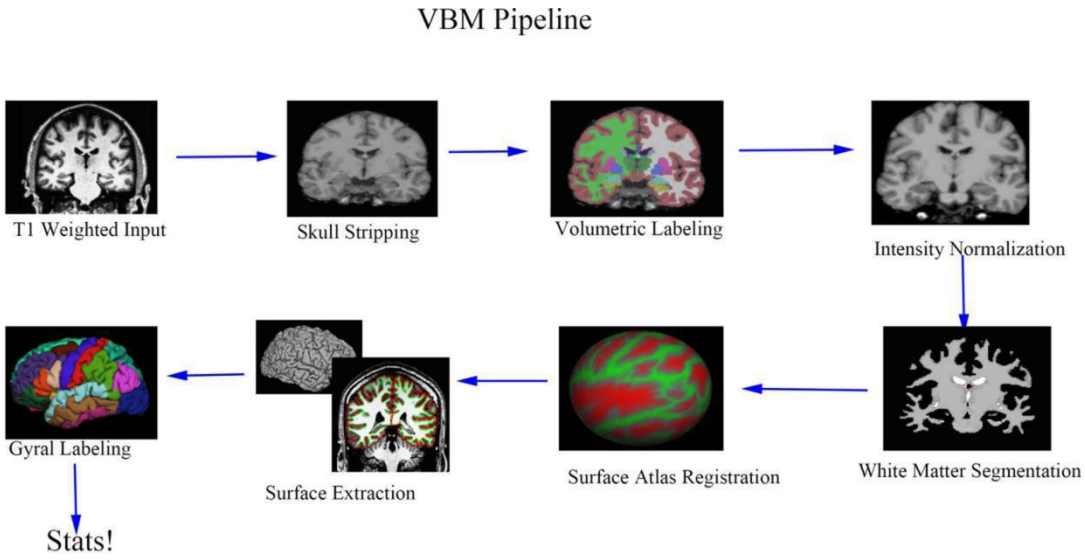

Fig 1. Showing the VBM Pipeline.

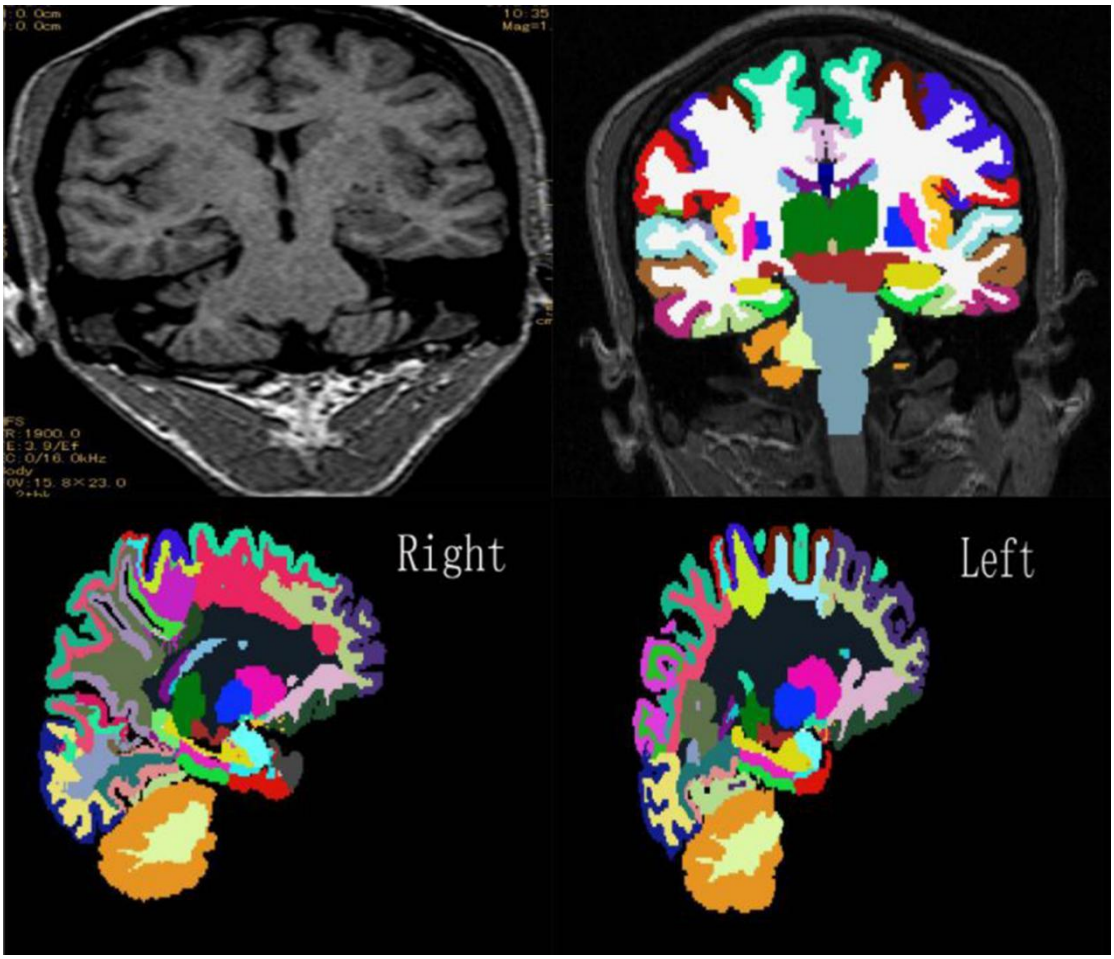

Fig 2. Case E6 from 1.5T epileptic patient, female, 32 years old, had epileptic seizure for 3 years and the EEG mainly shows the seizure mostly originates from the right temporal lobe and transfer to the left side. Figure showing right hippocampus smaller than left

TABLES

Table 1. MRI groups composition

Group	Epileptic cases	Normal controls
1.5T MRI	10	9
3.0T MRI	30	7

Table 2. Summarize of 946 patients

Total patients	Patients	Percentage	Total patients
Males	563	59.51%	946
Females	383	40.49%	
Number of MRI positive	623	65.86%	946
Number of MRI negative	323	34.14%	
Patients who had surgery	12	1.27%	Male=9, female=3

Table 3. 1.5T Epileptic Patients' Measurement

Case Number	Age	Hippocampus		Amygdala		MRI Findings
		Left Side (Volume mm^3)	Right Side (Volume mm^3)	Left Side (Volume mm^3)	Right Side (Volume mm^3)	
E1	34	4582.2	4791.3	1854.7	1876.6	Negative
E2	23	3222.4	3533.7	1334.4	1591.2	Negative
E3	33	4098.5	4690.6	1982.7	2055.1	Negative
E4	30	4545.4	4505.5	1739.2	1887.5	Positive
E5	39	3573.2	3939.4	1293.3	1600.1	Positive
E6	32	4015.7	2995	1515.7	1609.9	Positive
E7	23	4326.4	4458.7	1568.3	1780.2	Positive
E8	19	3606.8	3715.7	1242.7	1236.4	Positive
E9	36	3122.5	3837.5	1500.6	1760.8	Positive
E10	30	4348.9	4667.3	1816.4	1750.2	Positive

Table 4. 1.5T Normal Controls' Measurement

Case Number	Hippocampus		Amygdala	
	Left Side (Volume mm^3)	Right Side (Volume mm^3)	Left Side (Volume mm^3)	Right Side (Volume mm^3)
C1	3642.9	3791.1	1316.1	1513.2
C2	4543	4711.1	1784.5	1968.6
C3	3616.6	4047.7	1419.6	1711.1
C4	3990.7	4034	1277.1	1580
C5	4653.4	4732.2	1632	1844.6
C6	3756.4	4115	1349.2	1675.6
C7	3719.4	3916	1323.6	1446.8
C8	3736.6	4067.8	1404.8	1589
C9	4206.7	4301.8	1551.7	1780.1

Table 5. VBM analysis result for 1.5T MRI group

	SD volume (in mm3)		***P* value**
	Epileptic cases	**Normal controls**	
Left Hippocampus	3944.20±532.80	3985.08±394.42	0.227
Right Hippocampus	4113.47±598.51	4190.74±331.16	0.031
Left Amygdala	1584.80±255.06	1450.96±170.40	0.161
Right Amygdala	1714.80±223.05	1678.78±166.53	0.553

Table 6. Diagnosis of 30 Patients in 3.0T MRI Groups

Case Number	**Sex**	**EEG Diagnosis**	**Clinical Diagnosis**
E1	Female	Normal electroencephalogram	Epilepsy（GTCS）
E2	Female	Left anterior temporal discharge and slow activity	Epilepsy
E3	Female	Normal electroencephalogram	non-epileptic seizure
E4	Male	Bilateral anterior-middle temporal focal discharge and left temporal TIRDA	Temporal lobe epilepsy
E5	Male	Normal electroencephalogram	Epilepsy（GTCS）
E6	Female	Bilateral frontotemporal focal theta waves	Hysteria, Epilepsy
E7	Male	Normal electroencephalogram	Epilepsy
E8	Female	Focal discharge of left frontal and frontal midline	Epilepsy（GTCS）
E9	Male	Left temporal focal discharge	Epilepsy（GTCS）
E10	Female	Bilateral anterior temporal focal discharge	Temporal lobe epilepsy
E11	Male	Theta activity in left anterior-middle temporal area was observed in conscious period, and focal discharges in left frontal and left temporal area were observed in sleeping period.	Epilepsy
E12	Male	It can be seen that the short-to-long-range emission of high-amplitude sharp wave and sharp-slow wave is comprehensive.	Epilepsy
E13	Male	Normal electroencephalogram	Epilepsy (CPS)
E14	Female	Normal electroencephalogram	Epilepsy (GTCS, CPS)
E15	Female	Diffuse 5-7Hz theta activity with obvious frontal area	Epilepsy（sGTCS）
E16	Male	Normal electroencephalogram	Epilepsy
E17	Male	Generalized high amplitude 1-2Hz delta activity and mid-and long-range spike and slow-spike complex waves were observed on both frontal and temporal sides.	Epilepsy
E18	Female	Normal electroencephalogram	Epilepsy
E19	Female	Focal discharge in right anterior temporal region	Temporal lobe epilepsy
E20	Male	Focal discharges in bilateral anterior temporal region were observed on the left side.	Epilepsy
E21	Female	The right middle-posterior temporal mid-amplitude 7-8 Hz theta activity appeared in short range. Focal slow wave was considered to be related to right craniocerebral surgery.	Right temporal lobe epilepsy (right hippocampal sclerosis)
E22	Male	Bitemporal discharges and slow activity were common on the left side, and TIRDA was also visible.	Epilepsy

E23	Female	Focal discharges of bilateral frontal, frontal, central and central lines were observed, slightly on the left, and CPS originated in the right central and parietal areas was monitored.	Epilepsy
E24	Female	Synchronized issuance of single delta wave in left forehead and middle frontal temporal region during sleep	Epilepsy（sGTCS）
E25	Male	Visible bilateral anterior-middle temporal region 3-4 Hz theta/delta wavelength range, with the left anterior temporal as the main.	Symptomatic epilepsy
E26	Female	Normal electroencephalogram	Epilepsy
E27	Female	Normal electroencephalogram	Epilepsy（sGTCS）
E28	Male	Focal discharges in the right anterior temporal region were observed, and the high amplitudes of 4-5Hz waves in the right frontal, central and middle temporal regions were intermittently observed.	Epilepsy
E29	Male	Normal electroencephalogram	Epilepsy（sGTCS，CPS）
E30	Female	Background EEG is normal. Focal discharges and 6-7Hz theta activity of the right anterior temporal region can be seen during sleep.	Epilepsy (CPS)

Notes: GTCS: generalised tonic clonic seizure; sGTCS: secondary generalised tonic clonic seizure; CPS: complex partial seizure; SPS: simple partial seizur, θ/δTheta/delta wave is slow wave.

Table 7. 3.0T Epileptic Patients' Measurement

Case Number	Hippocampus		Amygdala	
	Left Side (Volume mm3)	Right Side (Volume mm3)	Left Side (Volume mm3)	Right Side (Volume mm3)
E1	3578.9	3853.1	1564.6	1713.5
E2	3669.2	4037.6	1143.5	1773.7
E3	3572.3	3955.5	1496	1656.2
E4	3015	4069.3	1737	2312.7
E5	4216.4	4468.7	2031.6	2095.4
E6	3445.6	3577.7	1444.2	1556.6
E7	3600.2	3925.3	1777.2	1819.5
E8	3465.3	3635.3	1376.6	1784.7
E9	3475.2	3867.4	1758.6	2024.6
E10	4484.2	4905	1820.1	2149.4
E11	3095.7	3300.3	1567.7	1741
E12	4039.1	4092.6	1670.1	1976.1
E13	4385.9	4298.4	2308.3	2636.8
E14	3160	3440.7	1443.8	1727.6
E15	4348.7	4403.1	2004.2	2494.4
E16	3523.9	3472.8	1612.4	1682.5
E17	3907.7	4179.9	1702.6	2150

E18	3292.6	2893.7	1318	1556.3
E19	3993.5	4291.2	1598.7	2135.6
E20	3614.8	3688.2	1548.5	1855.5
E21	3543.7	3830.1	1420.9	1462.7
E22	3878.5	3885.5	1825.7	1943.1
E23	3778.7	3950.7	1821	1824.1
E24	3341	3484.5	1295	1389.5
E25	2338.9	3407.2	1130.8	1278.6
E26	3745.5	3956	1780.1	1858.8
E27	3998.4	4484.9	1740.3	2172.8
E28	3500.5	3926	1513.6	2084
E29	3636.7	3909.1	1655	1786.5
E30	3439.7	3528.5	1420.5	1470.2

Table 8. 3.0T normal controls' measurement

Case Number	**Hippocampus**		**Amygdala**	
	Left Side (Volume mm3)	**Right Side (Volume mm3)**	**Left Side (Volume mm3)**	**Right Side (Volume mm3)**
C1	4135.2	4151.4	1877.8	1955.1
C2	3539.5	4027.5	1811.7	1862.1
C3	3509.5	3658.2	1384.8	1653.3
C4	3822.1	3595.6	1127.7	1430.2
C5	3989.1	4144.5	1599.3	1571.6
C6	3987.2	4248.7	1577.2	1786.5
C7	3694.9	4017.4	1631.5	1696.6

Table 9. VBM analysis result for 3.0T MRI group

	SD volume (in mm3)		***P* value**
	Epileptic cases	**Normal controls**	
Left Hippocampus	3636.19±442.72	3811.07±240.17	0.293
Right Hippocampus	3890.61±413.45	3977.61±252.84	0.322
Left Amygdala	1617.55±257.55	1572.86±252.21	0.788
Right Amygdala	1870.41±316.41	1707.91±177.89	0.144