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Characterization of Human Hippocampus using Textural Analysis in Epileptics patient

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Abstract

Hippocampal sclerosis (HS), characterized by selective neuronal loss and reactive gliosis in the hippocampus and other mesial temporal structures, is a common pathologic finding in temporal lobe epilepsy. Epilepsy affects 1–2% of the population, with temporal lobe epilepsy (TLE) the most common variant in adults. Texture analysis can provide useful information about the microstructure of the organ of interest. The objective of this study was to characterize the hippocampal tissues into two classes normal and epileptic. This is experimental study using MRI scanner, the texture were extracted from spatial gray level dependence matrix using a window of 20×20 pixels of angle zero and distance equal one pixel. The images were collected from MRI brain scans for 18 patients represent the classes of the study. A linear discriminant analysis using stepwise were used to classify the sample into the predefined classes. The stepwise selected number of features out of fifteen features as the most discriminant features for each hippocampal region. The result of this study showed that the total classification accuracy was 83.3%, 80.6%, 91.7%, and 79.6% for body, head, tail and sagittal respectively. The sensitivity was 72.2, 72.2, 94.4% and 79.6. The Specificity was 94.4%, 88.92%, 88.9% and 79.6% respectively. This study confirmed that it's possible to diagnose and differentiate between normal and epileptic hippocampus body, head, tail and sagittal and coronal texturally. The tail of the hippocampus is the most accurate site to differentiate between the classes when using texture extracted from SGLD matrix, due to its rich texture and the several edges with accuracy of 91.7% versus an accuracy of 83.3% , 80.6% and 79.6% for body, head and sagittal respectively. More studies in the hippocampus textural analysis should be carried out using variable widows and texture to improve the accuracy, follow up the epileptic patients after the surgical or drug treatment to ass the progress texturally.

Keywords: *Epilepsy, Texture Analysis*

Introduction

Epilepsy (from the Ancient Greek ἐπιληψία (epilēpsía) — "to seize") is a common chronic neurological disorder characterized by recurrent unprovoked seizures and loss of consciousness. These seizures are transient signs and/or symptoms of abnormal, excessive or synchronous neuronal activity in the brain [(1)].

Epilepsy affects 1–2% of the population, with temporal lobe epilepsy (TLE) the most common variant in adults. Clinical and experimental studies have demonstrated hippocampal involvement in the seizures underlying TLE. However, identification of specific functional deficits in hippocampal circuits associated with possible roles in seizure generation remains controversial. Significant attention has focused on anatomic and cellular alterations in the dentate gyrus. The dentate gyrus is a primary gateway regulating cortical input to the hippocampus and, thus, a possible contributor to the aberrant cortical-hippocampal interactions underlying the seizures of TLE. Alternate cortical pathways innervating the hippocampus might also contribute to seizure initiation. Despite this potential importance in TLE, these pathways have received little study[(2)]. Using simultaneous voltage-sensitive dye imaging and patch-clamp recordings in slices from animals with epilepsy, we assessed the relative degree of synaptic excitation activated by multiple cortical inputs to the hippocampus. Surprisingly, dentate gyrus-mediated regulation of the relay of cortical input to the hippocampus is unchanged in epileptic animals, and input via the Schaffer collaterals is actually decreased despite reduction in Schaffer-evoked inhibition. In contrast, a normally weak direct cortical input to area CA1 of hippocampus, the temporoammonic

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pathway, exhibits a TLE-associated transformation from a spatially restricted, highly regulated pathway to an excitatory projection with >10-fold increased effectiveness. This dysregulated temporoammonic pathway is critically positioned to mediate generation and/or propagation of seizure activity in the hippocampus [(2)].

The hippocampus is a major component of the brain. It belongs to the limbic system and plays important roles in the consolidation of information from short-term memory to long-term memory and spatial navigation. Like the cerebral cortex, with which it is closely associated, it is a paired structure, with mirror-image halves in the left and right sides of the brain, the hippocampus is located inside the medial temporal lobe, it lies beneath the cortical surface. It contains two main interlocking parts: Ammon's horn and the dentate gyrus [(3)].

In Alzheimer's disease, the hippocampus is one of the first regions of the brain to suffer damage; memory problems and disorientation appear among the first symptoms. Damage to the hippocampus can also result from oxygen starvation (hypoxia), encephalitis, or medial temporal lobe epilepsy. People with extensive, bilateral hippocampal damage may experience anterograde amnesia—the inability to form or retain new memories. There is also a general relationship between the size of the hippocampus and spatial memory. When comparisons are made between similar species, those that have a greater capacity for spatial memory, tend to have larger hippocampal volumes. This relationship also extends to sex differences: in species where males and females show strong differences in spatial memory ability, they also tend to show corresponding differences in hippocampal volume [(3)].

The hippocampus is considered by many to be the generator of temporal lobe epilepsy (TLE). This view largely is due to the frequent observation of the histopathology of sclerosis in the Sommer's sector and in the end folium of the hippocampus of TLE patients. In addition, surgical removal of the sclerotic hippocampus often improves this epileptic condition [(4)].

Objective

The general objective of this study was to analyze and texturally characterized hippocampus using classification techniques to explore the microstructure.

Materials and Methods

This is experimental study using MRI scanner with power was 1.5 tesla (Siemens, magnetom, avanto, 2004, Germany), Syngo viewer, Software of the textural analysis (IDL), Image acquisition. The population of the Study were right handed people, categorized into two groups:

Known epileptics, the other group is the normal volunteers who were apparently healthy. They were selected to match the study group regarding age, gender, handedness and body mass index. The data was collected from 18 patients, 9 suffered from epilepsy and 9 were normal. Inclusion criteria include, right hander patients, diagnosed as temporal lobe epilepsy, EEG showed temporally generated seizure discharge and on active therapy and regular follow up, we exclude, Left hander patients and controls, diabetics and hypertensive patients. Epileptic patients with psychosis and patients in whom MRI abnormalities were detected (such as opacities and space occupying lesions).

Patient position supine. The scan was T1, coronal sections, with multi-plenary reconstruction 39 Acquisition (MP-RA). Slice thickness is 0.9 mm with zero gaps between the slices. Time of inversion (TI) is 600 ms. time of recovery (TR) 1160 ms. time of echo (TE) 4.44 ms and flip angle 15 degree. For the study group, routine MRI applying the epilepsy protocol was done and reported by a consultant radiologist. The textural analysis a new logarithm has been developed in IDL to extract the features. It consist of three segments, the first one for the co-occurrence the second one is for the extraction of features and the third is the calling sequence program in order to move the window. Linear discriminant analysis was applied to classify the features into two classes; normal and epileptic, using stepwise method. The classification coefficient function for the epilepsy according to the discriminant analysis provides a basis for classifying not only the sample used to compute the discriminant function, but also to classify any other observations that can have value for all the features by generating a classification function. In this way, discriminant analysis can be used to classify other features into defined classes. The number of classification functions is equal to the number of classes. Each function allows the computation of a classification score for each feature by applying an equation, which takes the following form:

$$S_{i=a_i} + \sum_{j=1}^{n} w_{ij} \times F_i$$

Where:

S_i Is the resultant classification score for the i^{th} class.
i= 1, 2, 3...K with K being the numbers of classes,
a_i Is a constant for the i^{th} class,
W_{ij}, is a weight function for the j^{th} feature for the i^{th} class,
j= 1, 2, 3...n with n being the number of features.
F_i Denotes the value of the j^{th}features.

Thus, a classification is achieved by multiplying each feature for an individual case by its corresponding weight in the different classes and adding these products together in each class. This process results in a single classification score for each class. Once the classification score is computed, the case is thus classified as belonging to the class in which it has achieved the highest score,

and the process is continued in the same fashion for the rest of the features.

The data will be analyzed by using SPSS 18 under windows where classification technique will be used to classify the textural feature of the hippocampus into normal and abnormal one as well to show the error bars of the selected feature that separate the two classes.

Results and Discussion

Fifteen textural features were extracted from a number of sub-images (20x20 pixels) from different pathological hippocampal MRI images of body, head and tail that identified by an expert radiologists and EEG as epileptic or normal. The textural features vector was analyzed by linear regression analysis for selection of the best sub set of features that can be used to classify the sub-images into their respective class several features were selected as the most discriminant feature for each part of hippocampal regions which can be used to classify the images into two classes. Similarly is the linear discriminant analysis; which used to classify the textural featured pickup the same features.

The result of this study showed that classification accuracy of hippocampal body into normal and epileptic class was 83.3% with sensitivity of 72.2% and Specificity of 94.4 %. The discriminate features included inertia, correlation, difference entropy, sum variance, difference average, difference variance and information1 (Table 1). With the correlation and inormation1 were the most discernible features (Figure 2 - 3). The classification score function that can be used to classify the hippocampal body into normal or epileptic is as flows:

Normal score $_{(B)}$ = *(Inertia×-8.888) + (Correlation×7528.657) + (Entropy×62.115) + (sum variance×-.450) + (Difference average×133.747) + (Difference_variance×25.399) + (Information1×475.838) -3723.874.*
Epileptic score $_{(B)}$ = *(Inertia×-8.453) + (Correlation×7511.757) + (Entropy×60.889) + (sum variance×-.445) + (Difference average×130.352) + (Difference_variance×24.734) + (Information1×470.937) -3695.684.*

The classification of the hippocampal head into two classes revealed that the discriminate features included Inertia, Correlation, difference entropy, Difference average, Difference variance and Information1(Table 4). With the correlation and difference average showed a good discrimination (Figure 5- 6). The classification accuracy was 80.6% with sensitivity of 72.2% and Specificity of 88.92 %. This result showed a lower classification result relative to the body classification accuracy. This is might be attributed to the presence of amygdala which interfere with tissue of hippocampus in the extracting window, as well as the head will be shrunk in case of chronic epilepsy. The classification score function is used to classify the classes was as flows:

Normal score $_{(H)}$ = *(Inertia×16.028) + (Correlation×596.870) + (difference entropy×821.783) + (Difference average×-365.483) + (Difference variance ×-16.039) + (Information1×245.764)--1022.909*
Epileptic score $_{(H)}$ = *(Inertia×15.832) + (Correlation602.767×) + (difference entropy×813.647) + (Difference average×-361.915) + (Difference variance ×-15.914) + (Information1×228.561)-1017.031*

For the classification of the hippocampal tail gave a classification accuracy of 91.7% with sensitivity of 94.4% and Specificity of 88.9 % into normal and epileptic class the discriminate features included Inertia, IDM, Correlation, difference entropy, Difference average, Difference variance, Information1 and information2(Table 6). The textural feature correlation showed an excellent discrimination between the two classes. It is obvious that the feature correlation play a major role in the classification process for the body, head and tail. The classification results of the tail was far better than head and body this might be due to the crucial difference between the texture in case of normal and epileptic. The classification score function is used to classify the classes was as flows:

Normal score $_{(T)}$ = *(Inertia× 4.002) + (IDM× 7005.453) + (Correlation× -5437.314) + (difference entropy×-3077.004) + (Difference average×765.676) + (Difference variance×-12.548) + (Information1×14028.949) + (information2×220684.023) - 101063.971*
Epileptic score $_{(T)}$ = *(Inertia× 4.283) + (IDM× 6984.006) + (Correlation× -5331.712) + (difference entropy×-3059.506) + (Difference average×755.854) + (Difference variance×-12.643) + (Information1×14057.749) + (information2×220613.433) - 101097.212*

The classification of the hippocampal sagittal into normal and epileptic class the discriminate features included Entropy, Energy, IDM, sum entropy, difference entropy, and Difference average (Table 4-8). The classification accuracy was 79.6% with sensitivity of 79.6%and Specificity of 79.6 %. This result of classification was worse than the one that achieved earlier in the body, head and tail. Because the classification was done in hippocampus a one region rather than separate region even they appear in one view. The classification score function is used to classify the classes was as flows:

Normal score$_{(S)}$ = *(Entropy×369.551) + (Energy×8632.165) + (IDM×1735.439) + (sum entropy×-118.294) + (difference entropy×51.874) + (Difference average×20.987) -1570.875*
Epileptic score$_{(S)}$ = *(Entropy×366.477) + (Energy×8564.880) + (IDM×1709.650) + (sum entropy×-116.762) + (difference entropy×49.543) + (Difference average×20.870) -1538.864.*

In summary the result showed that the classification result was best in the tail where higher classification accuracy will be achieved followed by body and then head. The sagittal view score lower accuracy in respect to the other regions. The correlation is the most discriminate features in the epileptic tissues due to the fact that the diseased tissues tends to have the same cellular formation or texture, while in the healthy normal tissues has a histogensity. The result of this study agrees with the previous studies by Jafari-Khouzani, et al (2003 and 2011).

Table 1 the Classification Function Coefficients for body of hippocampus as calculated by using Fisher's linear discriminant functions

	Class	
	Normal	Epileptic
Entropy	1558.106	1548.993
Energy	1622.072	1318.899
Inertia	-95.888	-95.184
IDM	10862.916	10837.427
Correlation	-48606.658	-48577.396
Sum_average	8.115	8.052
sum_entropy	-3848.998	-3840.400
difference_entropy	-3533.235	-3529.259
sum_variance	3.725	3.728
Difference_average	1424.698	1417.743
Difference_variance	-14.556	-15.307
Information1	31326.102	31294.629
information2	449537.065	449157.239
(Constant)	-187264.141	-186891.310

Table 2 The Classification Results, of original grouped cases correctly classified

		Class	Predicted Group Membership		Total
			Normal	Epileptic	
Original	Count	Normal	17	1	18
		Epileptic	5	13	18
	%	Normal	94.4	5.6	100.0
		Epileptic	27.8	72.2	100.0

Table 3 The Classification Results, of original grouped cases correctly classified. Result versus the ground truth which is scored by EEG and a qualified radiologist

		Class	Predicted Group Membership		Total
			Normal	Epileptic	
Original	Count	Normal	43	11	54
		Epileptic	11	43	54
	%	Normal	79.6	20.4	100.0
		Epileptic	20.4	79.6	100.0

Table 4 The Classification Function Coefficients for Head of hippocampus as calculated by using Fisher's linear discriminant functions

		Class	Predicted Group Membership		Total
			Normal	Epileptic	
Original	Count	Normal	16	2	18
		Epileptic	5	13	18
	%	Normal	88.9	11.1	100.0
		Epileptic	27.8	72.2	100.0

Table 5 Site2 * classification Crosstabulation normal cases

Count				
		classification		Total
		normal	Epileptic	
site	Body	17	1	18
	Head	16	2	18
	Tail	16	2	18
	Sagittal	43	11	54
Total		92	16	108

Table 6 The Classification Results, of original grouped cases correctly classified

		CLASS	Predicted Group Membership		Total
			Normal	Epileptic	
Original	Count	Normal	16	2	18
		Epileptic	1	17	18
	%	Normal	88.9	11.1	100.0
		Epileptic	5.6	94.4	100.0

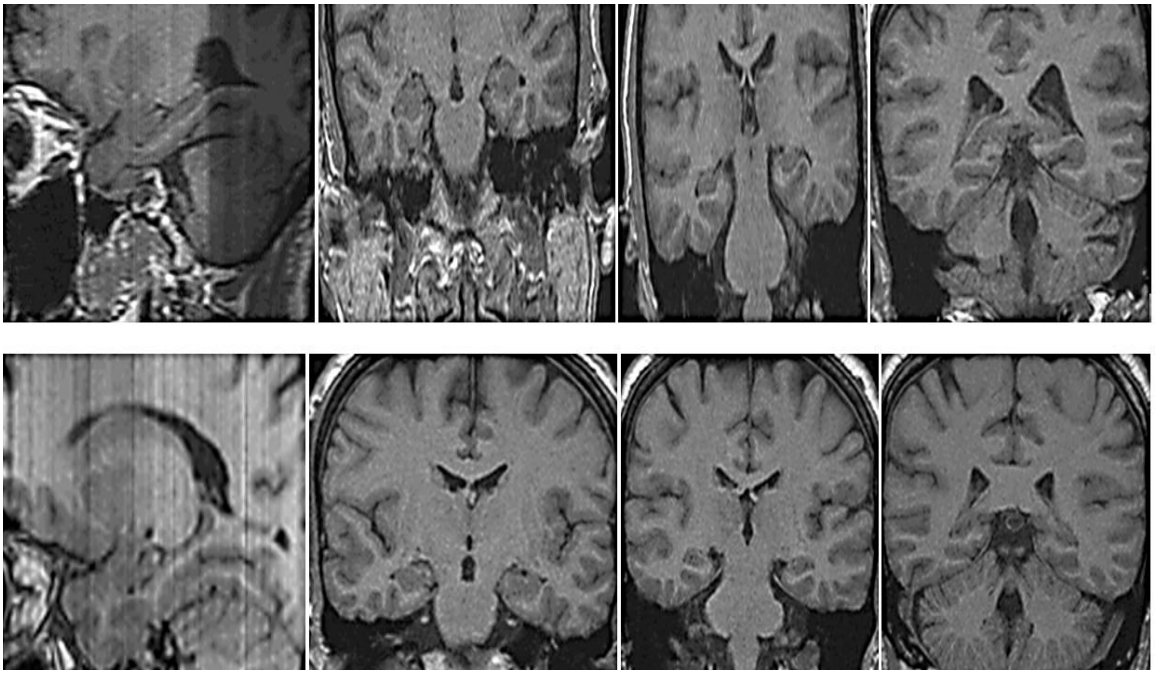

Figure 1 Eight MRI images of hippocampus

Conclusion

This study confirmed that it's possible to diagnose and differentiate between normal and epileptic hippocampus body, head, tail and sagittal and coronal texturally. The tail of the hippocampus is the most accurate site to differentiate between the classes when using texture extracted from SGLD matrix, due to its rich texture and the several edges with accuracy of 91.7% versus an accuracy of 83.3% , 80.6% and 79.6% for body, head and sagittal respectively. The hippocampal tail plays an important role in the process of moving the memories from the short term to the long term memory, hence memory issues is a common effect of epilepsy it is justified that the textural analysis gives high accuracy. Textural analysis is more accurate than the volumetric or the human eye based diagnosis because texture analysis is solely objective while the later method subjectivity play a major role in the judgment, so it possible to add it to the radiologist works station as an adding diagnostic tool.

Recommendations

More studies in the hippocampus textural analysis should be carried out using variable widows and texture to improve the accuracy follow up the epileptic patients after the surgical or drug treatment to ass the progress texturally.

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