Hippocampus Volume and Texture Analysis for Temporal Lobe Epilepsy

Kourosh Jafari-Khouzani, Hamid Soltanian-Zadeh, *Member, IEEE*, and Kost Elisevich

Abstract— **It has been previously shown that intensity and volume features of the hippocampus from MR images of the brain are useful in detecting the abnormality and consequently candidacy of the hippocampus for temporal lobe epilepsy (TLE) surgery. In this paper, we have studied and compared volume and texture features of hippocampus for TLE lateralization. Volume and some features describing the intensity non-uniformities are used. We use manual segmentation of the hippocampi from T1 weighted images and map them to the FLAIR images. Wavelet features as well as mean and variance of the hippocampus intensities of the FLAIR slices are used as texture features. A dataset of 55 patients with 28 right and 27 left abnormal sides was used in the experiments. Experimental results show that the volume and intensity features are useful in determining the abnormal side.**

I. Introduction

EPILEPSY is one of the most common disorders of the nervous system, which causes seizure by a temporary change in the electrical functioning of the brain. Temporal lobe epilepsy (TLE) is a type of epilepsy where the abnormal electrical discharges arise in the temporal lobe of the brain. Hippocampal damage is the most common pathology underlying TLE. Localization of the abnormal zones in the brain is an important task in the treatment of temporal lobe epilepsy.

Recently shape and MR image intensity features of the brain structures have been used for diagnosis of abnormal zones. It has been shown that the determination of structural and volumetric asymmetries in the human brain from MR images provides critical data for the diagnosis of focal abnormality [1],[2].

In our previous work [3]-[5], we used wavelet, wavelet packet, and multiwavelet texture features to specify the candidate hippocampus for surgery in temporal lobe epilepsy.

Duchesne et al. [6] employ texture analysis to classify the temporal lobe epilepsy using MR image appearance. They use a volume of interest (VOI) around the hippocampus instead of hippocampus alone. For classification of the images, models of the intensity characteristics and shape deformations of the VOI are constructed and concatenated into an appearance model for the volume. For the VOI with n pixels, they consider an n-dimensional space and use the principal component analysis (PCA) to find the eigenvectors as orthonormal bases spanning n-dimensional allowable space. In this way, they consider both gray-level intensities and shape deformations.

Yu et al. [7] try to detect epilepsy by texture analysis of MR brain images in the lithium-pilocarpine rat model. They use three texture parameters derived from co-occurrence matrix to characterize structural abnormalities. Bernasconi et al. [8] study the first-order and second-order texture features to assess structural integrity of mesial temporal lobe structures (hippocampus, amygdala, and entorhinal cortex). They do a similar texture analysis work for temporopolar cortex and white matter in TLE by incorporating volumetric measurements [9]. Yu et al. [10] use first-order and second-order texture features to detect abnormality of the hippocampus in TLE.

In this paper, we study the volume and texture features of 55 patients with TLE, 28 with right and 27 with left abnormal side. Volume and some features describing the intensity non-uniformities are used. We use manual segmentation of the hippocampi from T1 weighted images and map them to the FLAIR images. Wavelet features as well as mean and variance of the hippocampus intensities of the FLAIR images are used as texture features. Experimental results show that the hippocampus geometry and intensity features are useful in determining the abnormal side.

II. Feature Extraction

The features are extracted from coronal images using Fluid Attenuated Inversion Recovery (FLAIR) with TR=10002 ms, TE=119 ms, FOV=200×200 mm2, Mat=256×256, Slice thickness=3.0 mm, and 2.0 NEX. The hippocampi are manually segmented from T1 weighted images and then mapped to the FLAIR images using registration parameters between the two image sets. Fig. 1 shows a manual segmentation of the hippocampus from a T1 weighted image. Having the 3D surface of the hippocampus and FLAIR hippocampus slices, we calculate the volume and texture features in three different categories as described in the following subsections.

A. Mean and Variance

It is known that the abnormal hippocampus usually has higher intensity compared with the normal hippocampus in

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FLAIR images [3]. Therefore, mean and variance of all hippocampus slices from FLAIR images can be used as discriminating features. We divide the left side features by the right side features to get the final features for each patient.

B. Wavelet Features

Wavelet transform provides a spatial/frequency representation of a signal. For each FLAIR hippocampus slice, we calculate two levels of ordinary wavelet decomposition to produce 7 subbands as depicted in Fig. 2. Energy features are calculated as follows for each subband:

$$\text{energy} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} I^2(x, y) \qquad (1)$$

where $I(x, y)$ shows the subband elements and M and N are the dimensions of each subband. Since the segmented hippocampus slices are not rectangular, we make them rectangular by the method described in [3]. In this method, each slice is first inscribed in a rectangle, then dilated repeatedly using a 3×3 window. The dilated part is repeatedly filled by average of its 8-connected neighbors. Since the mean and variance features are evaluated separately, we make the wavelet features independent of the intensity mean value and variance of hippocampus by normalizing the intensities of each slice to have a mean value of zero and variance of one.

In this way, we create seven energy features for each slice. The features are averaged over the hippocampus slices and then the features of the left hippocampus are divided by their corresponding features of the right hippocampus. The computed ratios are then used as the final features.

C. Volume Features

It has been shown that hippocampus volume has correlation with its abnormality [2]. We use the ratio of the left and right hippocampi volumes as the first feature. Other features are calculated as follows.

Cross section area variability: The areas of all hippocampus slices and then the standard deviation of the areas are calculated. The ratio of the produced features for left and right sides is calculated as a feature for classification.

Irregularity: The distances of the centers of the slices are calculated from the line that connects the first and last slices centers. The average of the distances shows how much the hippocampus volume resembles a cylinder. The small value of this feature shows that the hippocampus has small irregularities. On the other hand, large value of the feature shows that the hippocampus has more curves and bends.

III. Classification

The samples are classified into left and right abnormal sides by a linear classifier shown in Fig. 3. The classifier is trained using some training samples. We use the EEG phase II results for each patient as the gold standard for determining the abnormal side.

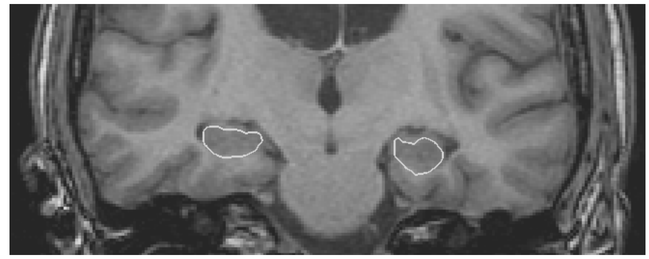

Fig. 1. Manual segmentation of the hippocampi from the T1 weighted images.

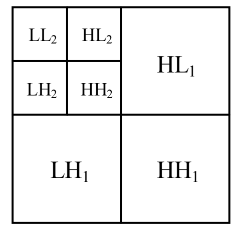

Fig. 2. Subbands produced by two levels of wavelet decomposition.

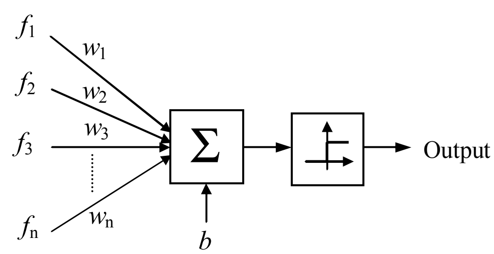

Fig. 3. Structure of a linear classifier.

IV. Experimental Results

A dataset of FLAIR images of 55 temporal lobe epileptic patients with 28 right and 27 left abnormal sides was used in the experiments. The three introduced sets of features were examined separately using linear classifiers. The classifiers are trained using features from all the data set. The training error is reported as the classification error.

Using the mean and variance features, we obtained an accuracy of 85.5%. Fig. 4 shows the scatter plot of mean and variance features and the boundary of the employed linear classifier. The "R" and "L" symbols denote the patients with right and left abnormal hippocampi, respectively. As shown there is a good separation between the two classes with only 8 misclassifications.

We used db20 wavelet basis to create wavelet features. A correct classification percentage of 74.5% was obtained using seven wavelet features and a linear classifier. This shows that there may be additional information in the hippocampus FLAIR slices than just mean (that doctors see from the image) and variance of the intensities. Fig. 5 shows the scatter plot of two of the wavelet features corresponding to two low-resolution subbands, named *e*1 and *e*2.

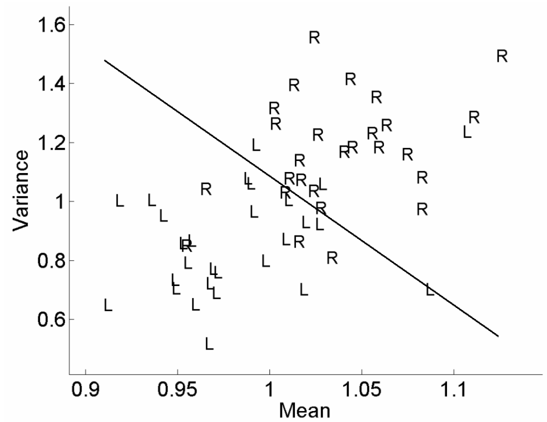

Fig. 4. Scatter plot of the mean and variance features. The symbols "R" and "L" respectively show the right and left abnormal hippocampi. The boundary of the linear classifier shows that there is a good separation between the two classes.

The separability of the features is not very clear in this figure, since only two features of the seven features have been shown here.

Using the texture features together with the mean and variance and a linear classifier, we obtained an increased accuracy of %92.7.

The volume ratio, cross section area variance, and irregularity features, respectively resulted in accuracies of 85.5%, 72.0%, and 60%. Fig. 6 shows the scatter plot of the volume and cross section area variance features, which together provide an accuracy of 85.5%. Although the cross section area variance feature has an accuracy of 72% alone, its combination with volume does not increase the accuracy. This is noted by the horizontal nature of the decision boundary in Fig. 6.

V. Conclusion

We have studied the hippocampus volume and texture features of TLE patients. The location of seizure onset as determined by the EEG methods and the postoperative outcomes were considered as the gold standard. Manual segmentation results from T1-weighted images were mapped to the FLAIR images. Experimental results showed that there is more information in the hippocampus FLAIR slices than just mean and variance of the intensities. This information together with the mean and variance features has resulted in 92.7% accuracy in classification of the hippocampi to the left or right abnormal side. The volume features are also shown to contain some information related to the abnormality of the hippocampus. Volume feature was the most discriminating feature among the features we used for the hippocampus geometry.

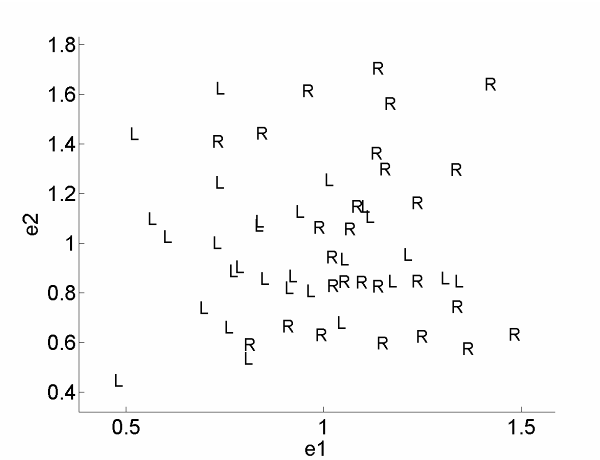

Fig. 5. Scatter plot of two of the wavelet features. The symbols "R" and "L" respectively show the right and left abnormal hippocampi. The features e_1 and e_2 are two of the wavelet features corresponding to the two low-resolution subbands.

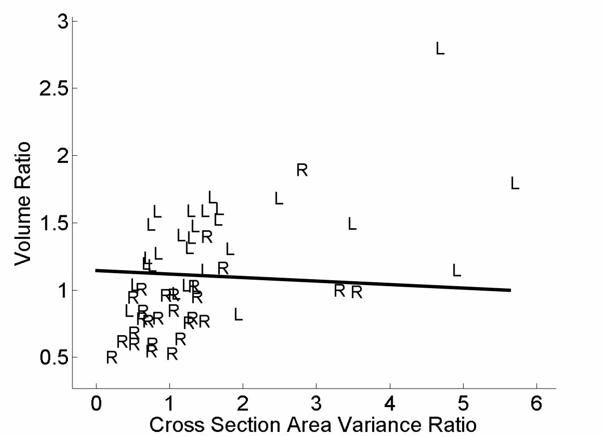

Fig. 6. Scatter plot of the volume and cross section area variance ratios. The symbols "R" and "L" respectively show the right and left abnormal hippocampi.

References

[1] C.R. Jack, R.C. Petersen, P.C. O'Brien, and E.G. Tangalos, "MR-based hippocampal volumetry in the diagnosis of Alzheimer's disease", *Neurology*, 42, no. 1, pp. 183-188, 1992.

[2] F. Cendes, F. Andermann, P. Gloor, A. Evans, M. Jones-Gotman, C. Watson, D. Melanson, A. Olivier, T. Peters, I. Lopes-Cendes, and G. Leroux, "MRI volumetric measurement of amygdala and hippocampus in temporal lobe epilepsy", *Neurology*, 43, no. 4, pp. 719-725, 1993.

[3] K. Jafari-Khouzani, M.-R. Siadat, H. Soltanian-Zadeh, and K. Elisevich, "Texture analysis of hippocampus for epilepsy", *Proc. SPIE: Medical Imaging*, 5031, pp. 279-288, Feb. 2003.

[4] K. Jafari-Khouzani, H. Soltanian-Zadeh, K. Elisevich, and S. Patel, "Comparison of 2D and 3D wavelet features for TLE lateralization", in *Proc. SPIE:* Medical Imaging, 2004, vol. 5369, no. 1, pp. 593-601.E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," *IEEE Trans. Antennas Propagat.*, to be published.

[5] K. Jafari-Khouzani, H. Soltanian-Zadeh, and K. Elisevich, "Texture analysis of high-resolution FLAIR images for TLE", in *Proc. SPIE:* Medical Imaging, 2005, vol. 5747, pp. 1348-1355.

[6] S. Duchesne, N. Bernasconi, A. Bernasconi, and D.L. Collins, "On the classification of temporal lobe epilepsy using MR image appearance", *Proc. 16th Int. Conf. on Pattern Recognition*, 1, pp. 520-523, 2002.

[7] O. Yu, C. Roch, I.J. Namer, J. Chambron, and Y. Mauss, "Detection of late epilepsy by the texture analysis of MR brain images in the lithium-pilocarpine rat model", *Magnetic Resonance Imaging*, vol. 20, pp. 771-775, 2002.

[8] N. Bernasconi, S. B. Antel, and A. Bernasconi, "Texture analysis in mesial temporal lobe epilepsy", *Proc. Int. Mag. Reson. Med.*, 11, pp. 2021-2021, 2003.

[9] N. Bernasconi, D. Kinay, F. Andermann, S. Antel and A. Bernasconi "Analysis of shape and positioning of the hippocampal formation: an MRI study in patients with partial epilepsy and healthy controls", *Brain*, 128 (Pt 10), pp. 2442-2452. July 2005.

[10] O. Yu, Y. Mauss, I.J. Namer, and J. Chambron, "Existence of contralateral abnormalities revealed by texture analysis in unilateral intractable hippocampal epilepsy", *Magnetic Resonance Imaging*, vol. 19, no. 10, pp. 1305-1310, 2001.R. W. Lucky, "Automatic equalization for digital communication," *Bell Syst. Tech. J.*, vol. 44, no. 4, pp. 547–588, Apr. 1965.