ANALYSIS OF DIFFERENCES BETWEEN SPECT IMAGES OF THE LEFT AND RIGHT CEREBRAL HEMISPHERES IN PATIENTS WITH EPILEPTIC SYMPTOMS

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Abstract: The aim of his work was examination of asymmetries in activity of the left and right cerebral hemispheres as well as localization and contouring of the regions of reduced or increased activity on the basis of single photon emission computer tomography (SPECT) images. The mean and standard deviation of normalized intensities inside the contoured areas of images, entropy based on intensity histograms and Chen's fractal dimension were calculated.

1 INTRODUCTION

The aim of his work was examination of asymmetries in activity of the left and right cerebral hemispheres as well as localization and contouring of the regions of reduced or increased activity on the basis of single photon emission computer tomography (SPECT) images (Prószyński, 1989). Advantage of this technique is possibility of brain activity map acquisition at the time of radiotracer injection during seizures though the image registration is done one hour after seizure. SPECT imaging method allows better spatial localization of seizure source than the analysis of EEG signal. Simultaneous EEG signal registration allows to qualify exactly the moment of seizure onset when radiotracer injection could be done to register an unequivocal image. The mean and standard deviation of normalized intensities inside the contoured areas of images were calculated. Methods like entropy based on intensity histograms and Chen's fractal dimension were also applied.

2 MATERIALS

The scintigraphic examinations of cerebral perfusion in 6 patients were performed in the Department of Nuclear Medicine of the Medical Academy of Warsaw.

From each patient after delivering them the HMPAO Tc99m isotope in interictal phase several transverse cerebral images have been acquired. In the below-shown series of images they have been ordered from the basis to the top of the examined brain; left side of an image corresponds to the right side of the brain and vice versa.

An increased/reduced cerebral perfusion corresponds to a higher/lower isotope density and is manifested by an increased/ reduced image luminance registered in an 8-bits scale and normalized to the maximum (256 steps) luminance level. Images of 128x128 pixels size were registered. In table 1 several examples of medical description of the corresponding cases are given.

3 METHODS

In order to evaluate the effectiveness of various methods the comparative analysis of the images of the left and right cerebral hemispheres was performed by using three independent methods:

1. comparison of the mean and standard deviation values,
2. comparison of estimated entropies,
3. comparison of fractal dimensions.

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Table 1: Kind of perfusion and localization of the brain region by medical assessment.

Patent name (slices number)	Kind of perfusion	Localization on the image	Brain region
CHM (16)	Reduced	Right upper	Left frontal lobe
KOS (15)	Disabled	Right	Left temporal lobe
SIE (15)	Reduced	Right	Left temporal lobe
SZY (14)	Disabled	Left upper	Right frontal temporal lobe
TWO (15)	Disabled	Left upper	Right frontal temporal lobe
ZIE (11)	Increased	Left	Right temporal lobe (numerous movement artifacts)

3.1 The Mean and Standard Deviation of Normalized Intensities

The images were processed and analyzed using standard Image Pro Plus (Media Cybernetics) and Microsoft Excel software packages (Russ, 1995). Each image was geometrically divided into the left and right parts. For a direct visual assessment of monochromatic images they also were visualized in pseudocolors. Then the left and right cerebral hemispheres were automatically contoured and the mean and standard deviation of normalized luminances inside the contoured areas of images were calculated. At the next step the surrounding background, outside a mask selecting the object of interest, from the images was reduced to the 0 level.

3.2 Entropy based on Intensity Histograms

The Shannon's entropy (Shannon, 1948) of a probability distribution of image intensities is defined as:

$$S = -\sum_{i=1}^{N} p_i \log p_i \quad , \quad \sum_{i=1}^{N} p_i = 1 \qquad (1)$$

where

p_i , i=1,…N - probability of i-th intensity level.

Entropy based on intensity histogram (Kuczyński and Mikołajczyk, 2003) can be estimated as:

$$p_i = g_i \,/\, g_{total} \qquad (2)$$

where g_i - number of pixels with intensity i;
g_{total} - total number of pixels;
N - number of image gray levels.

Entropy is a measure of information. The bigger are changes of pixel intensities the bigger is the entropy. In this method only a total histograms are used to calculate entropy therefore the spatial information is lost.

3.3 Chen's Fractal Dimension

For image matrices with dimension N x N a multi-scale vector of difference intensity MSID = [ri(s1),ri(s2),… ri(sk)], where ri(sk) – mean intensity of all pairs of pixels at the distance sk, was defined (Chen, 1989).

If I(x,y) is a measure of intensity (gray level at point with (x,y) coordinates), then:

$$ri(sk) = \sum_{x1=0}^{N-1} \sum_{y1=0}^{N-1} \sum_{x2=0}^{N-1} \sum_{y2=0}^{N-1} (|I(x2,y2) - I(x1,y1)|) \,/\, \text{number of pixel pairs for sk scale} \qquad (3)$$

There are the following relations for coordinates x1, y1, x2, y2:

$$sk = \sqrt{(x2-x1)^2 + (y2-y1)^2} \qquad (4)$$

$$|\Delta I| = |I(x2,y2) - I(x1,y1)| \sim |\Delta x|^H \qquad (5)$$

where

H – Hurst's exponent (fractal dimension Df = 3-H);
Δx – the distance between points with coordinates (x2,y2) and (x1,y1).

The logarithms of both sides were calculated:

$$\log |\Delta I| \sim H \cdot \log |\Delta x| \qquad (6)$$

4 RESULTS

4.1 The Mean and Standard Deviation of Normalized Intensities

The comparative analysis was performed in 6 patients for which mean values and standard deviations of luminance on the left and right cerebral hemispheres were measured. In order to make the results independent on the mean brightness level data were normalized by calculation of the ratio of the difference to the sum of mean brightness in the hemispheres. The regions of reduced/increased perfusion were localized using the above-described image segmentation method. The results of calculations (for two patients mentioned above) are shown in Fig. 1. The horizontal axes indicate the numbers of consecutive slices. The normalized values of mean brightness differences for 6 patients are shown in Fig. 2.

4.2 Entropy and Fractal Dimension

Entropy and Chen's fractal dimension were calculated for all quarters of brain (upper-left, upper-right, down-left, down-right) in 8 ranges of pixel intensity: 1-32, 33-64, 65-96, 97-128, 129-160, 161-192, 193-224, 225-256. Each of four regions of brain contains 63 x 63 pixels. The ratio of the difference

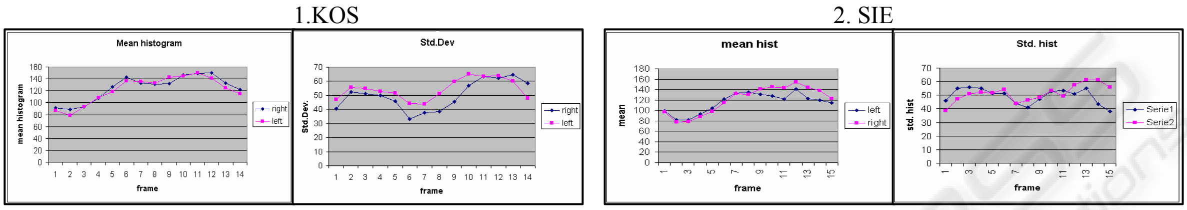

Figure 1: Mean values and standard deviations of luminance for the left and right cerebral hemispheres, patients KOS, SIE.

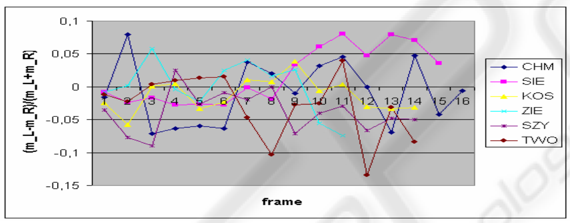

Figure 2: Normalized values of mean brightness differences for 6 patients.

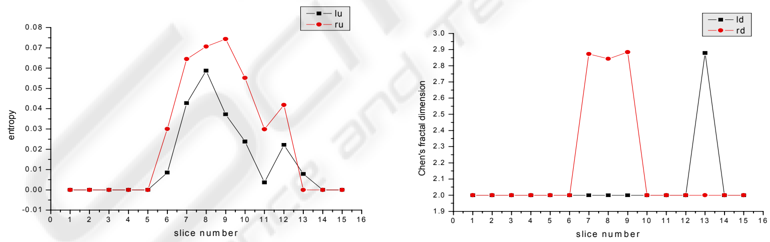

Figure 3: Entropy and Chen's fractal dimension graphs for the higher level of pixels intensity (225-256) for patient KOS in regions of brain in which differences of these measures between both hemispheres are bigger than 10%.

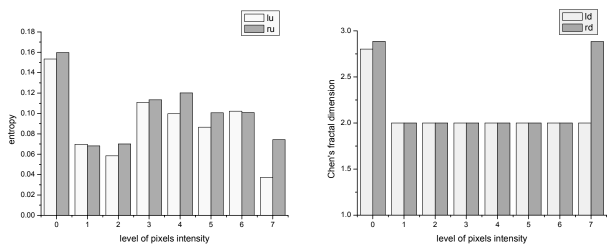

Figure 4: Histogram of entropy and Chen's fractal dimension for all levels of pixels intensity for patient KOS in regions of brain in which differences of these measures between both hemispheres are bigger than 10%.

to the sum of entropy and Chen's fractal dimension for left upper/down respect of right upper/down quarter of brain was calculated. Entropy results confirmed the medical observations (Table 2). Graphs of entropy and Chen's fractal dimension for the higher level of pixel intensity (225-256) in regions of brain for which the differences of these measures between both hemispheres are bigger than 10% are showed on Fig. 3. Histograms of entropy and fractal dimension (Fig.4) show significant differences for the higher level of pixel intensity.

Table 2: Number of slices for which the rate of the difference to the sum of S or Df in the left and right hemispheres in range with the biggest intensity of pixels (from 193 to 256) has values bigger than 0.1 for four regions of brain (UL-upper left, UR-upper right, DL-down left, DR-down right).

Pacjent name	Number of slices for entropy UL-UR-DL-DR	Slices number for fractal dimension UL-UR-DL-DR
CHM	1-7-7-0	1-1-0-4
KOS	3-7-8-0	6-1-1-3
SIE	0-9-3-5	1-0-0-0
SZY	10-0-9-0	0-0-0-0
TWO	3-3-2-0	1-0-0-5
ZIE	1-7-4-2	1-1-0-0

5 CONCLUSIONS

The above presented methods of cerebral SPECT images analysis based on simple image processing methods and calculation of basic statistical parameters are effective tools for a preliminary assessment of cerebral perfusion in diagnosis of epileptic and/or cerebral ischemic patients. It was found that for reduced perfusion entropy increases and Chen's fractal dimension decreases. Entropy based on the intensity histograms permits on automatic perfusion asymmetry evaluation between left and right brain hemisphere taking into account only the bigger intensities of pixels (in the range from 193 to 256). Entropy is a better measure to estimate the global intensity however without information about spatial distribution. For identification of epileptic seizure localization (concentration of high intensity pixels) Chen's fractal dimension seems to be the better measure.In further work calculations for more patients and for group of healthy volunteers should be done. Chen's fractal dimension could be calculated for less-dimensional matrices (8 x 8) in sliding window to construct map of fractal dimension of the whole brain. It will allow to estimate better the utility of this method to localize the epileptic seizure and to compare different regions of interest (ROIs).

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