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CHARACTERIZATION OF MYOCARDIUM MUSCLE BIOSTRUCTURE USING FIRST ORDER FEATURES

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Echocardiography analysis technique plays an important role in correctly establishing the diagnosis. The quantitative analysis is applied on selected image texture to differentiate between normal and infarcted myocardial biostructures. In this study we computed the first order statistical features in frames end-systole and end-diastole for two diagnosis, healthy and myocardial infarction or heart attack. In order to follow up the evolution of the statistical parameters values for healthy and infarcted myocardial biostructures, the samples were copped from apical two-chamber (A2C). A control group of twelve subjects, from which six are normal and six suffer from myocardial infarction were evaluated. Quantitative texture measurements of the first order features as mean gray level, skewness, kurtosis, and entropy were used.

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1. Intoduction

Living organisms are organized in two forms of matter: a biostructured form and the coexistent molecular matter. Under the influence of the various metabolic inhibitors or various physiological, pathological and experimental conditions the cardiac biostructure features can be partially and reversibly deteriorated or irreversibly destroyed.

Echocardiographic examination uses the physical properties of sound. It is based on very high frequency sound pulses that travel through the thoracic cavity, reflect off cardiac structures, and return to the transducer to be processed into images [1].

There are a lot of quantitative statistical parameters of the heart texture used to analyze the state of myocardium. Most often, first order statistics, second order statistics or high order statistics features were used. Over the last years, many studies were developed in order to differentiate between normal and abnormal myocardium or for identification various cardiomyopathic abnormalities through the analysis of the 2D-echocardiography images [2-4].

Echocardiograms highlight the damages of the myocardium biological tissue. Unfortunately, these deteriorations of the muscle texture are imperceptible to the human eye. Also, it is extremely difficult for the human eye to perceive and evaluate the tissue granularity and fibres direction.

In order to analyse the heart tissue and evaluate myocardium on the base of statistical parameters of the heart texture alterations we focused our analysis on the extraction of the first order features using echocardiography images from 12 patients from which 6 healthy patients and 6 patients suffer from myocardial infarction. In order to compute these first order features of interest such as mean, standard deviation, skewness, kurtosis and entropy the extracted samples from myocardium wall were performed (see Figs 1). They were extracted using samples cropped

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from apical two-chamber (A2C) view. As the result of the myocardium wall being very thin, the dimensions of the samples must be between 900-1000 pixels [5] or 16x16 pixels [6].

This paper is organised as following: Section 2 represents an overview of the applicability of the first order features on echocardiography images. Section 3 contains the mathematical description of the second order statistics features. The experimental results are given in Section 4. Finally, the paper is concluded in Section 5.

2. Previous work

Many researchers use these first order statistical parameters in order to obtain both quantitative and qualitative information from two-dimensional echocardiography images [7-14]. Various diseases have been characterized using different parameters based on gray level histogram. A lot of studies published in the field of myocardial texture used the mean gray value method [7-9]. As an example, during the diagnosis stage of the myocarditis Liback *at al.* [7], has been extracted the clinical values of echocardiographic tissue and besides the second order features and high order features they used the mean gray value. In their study, Dagdeviren *et al.* [8] suggested a relation between the mean gray value and quantitative ultrasonic textural alternation of the myocardium. In the trial to indentify the viability of the myocardial segment with a resting dyssynergy, E. Marini *et al.*[9] used also the mean gray values. In order to diagnose the myocardial amyloidosis B. Pinamonti *et al.* [10] proposed the first order quantitative texture measurement as mean gray value, skewness, kurtosis, energy and entropy. L. Kahl *et al.* [11] also characterized the myocardium tissue using the mean, standard deviation, entropy, skewness and kurtosis. Having that objective “to test the hypothesis that quantitative analysis of two-dimensional echocardiographic gray-level distributions” facilitates the detection of the early changes in acoustic properties of human diabetes myocardium, D. Bello *et al.* [12] successfully used the parameters as mean gray level, standard deviation, skewness and kurtosis in accomplishing this objective. All first order parameters were used by Bhandari and Navin [13] for myocardial texture characterization by 2D echocardiography in order to identify various infiltrative and degenerative processes in the heart wall through echo patterns myocardial histopathologic features correlation. Based on the results provided by histogram of gray level frequency distribution, F. Pizzarelli *et al.* [14] established a relationship between the parameters derived by ultrasonic myocardial characterization in dialysis patients and the mortality rate.

3. Mathematical description of the second order statistics features

The statistical methods are usually used to analyze the spatial distribution of the gray values. Moreover, the first order features allow estimating the properties of the individual pixel value and avoiding the analysis of the spatial interaction between pixels. In other words, the first order statistics of the gray level histogram describe the overall number of pixels having a certain gray level but independent of their location in the image [15].

The histogram of an image represents the relative frequency of occurrence of the various gray levels in the image. The first-order histogram is defined as

$$p(z_i) = \frac{number\ of\ \ pixels\ with\ value\ I}{number\ total\ of\ \ pixels} \tag{1}$$

Based on intensity levels of the histogram we can define some descriptive quantities [15]: The mean describe the gray value of the distribution:

$$\mu = \sum_{i=0}^{N-1} z_i\, p(z_i) \tag{2}$$

The mean is a measure of spreading of the distribution from the mean value:

$$\sigma^2 = \sum_{i=0}^{N-1} (z_i - \mu)^2 p(z_i) \tag{3}$$

The entropy is a measure of randomness of the gray level distribution:

$$e = -\sum_{I=0}^{N-1} p(z_i) \log_2 p(z_i) \tag{4}$$

Skewness is a measure of symmetry, or more precisely, the lack of symmetry [16]:

$$s = \frac{\frac{1}{N}\sum_{i,j\in R}(z_i - \mu)^3}{\left(\sqrt{\sum_{i,j\in R}\left(z_i^{\,2} - \mu^2\right)}\right)^3} \tag{5}$$

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution:

$$k = \frac{\frac{1}{N}\sum_{i,j\in R}(z_i - \mu)^4}{\left(\sqrt{\sum_{i,j\in R}\left(z_i^{\,2} - \mu^2\right)}\right)^4} \tag{6}$$

where, z_i is a random variable indicating intensity, $p(z_i)$ is the histogram of the intensity levels in a region, *N* is the number of possible intensity levels.[14]

4. Experimental results

In this study, the hardware experiment environment was Intel (R) Core (TM) 2 Duo CPU T 5900, 2.20 with 3G RAM, and the programming environment is the MATLAB R2009a. The images used for the analysis are acquired from scanning systems, VIVID E9 and GE HORTEN MOK WAY using curvilinear probe with transducer frequency of 3.5 MHz. All the echocardiography images of the heart used in this study were captured from the same machine and then digitized with 512 x 524 pixels and 256 grey-level resolutions.

Analysis of the US heart texture using the first order statistical features implies to crop one region of interest (ROI) from myocardium wall as is showed in Figure 1 where an apical two chamber (A2C) view and ROIs from basal inferior zone for healthy and myocardial infarction patients are presented.

Myocardium tissue was estimated analysing 24 ROIs not lesser than 900-1000 pixel [5]. For each echocardiography image from 12 patients, the ROIs were cropped automatically from apical two chamber area. After the cropping operation, the samples were used to extract the first order statistical features for end-systole and end-diastole frames for six healthy patients and six patients with myocardial infarction. The results are stored in Table 1.

In Figures 2 and 3 it is showed the evolution of the statistical parameters for each category of patients.

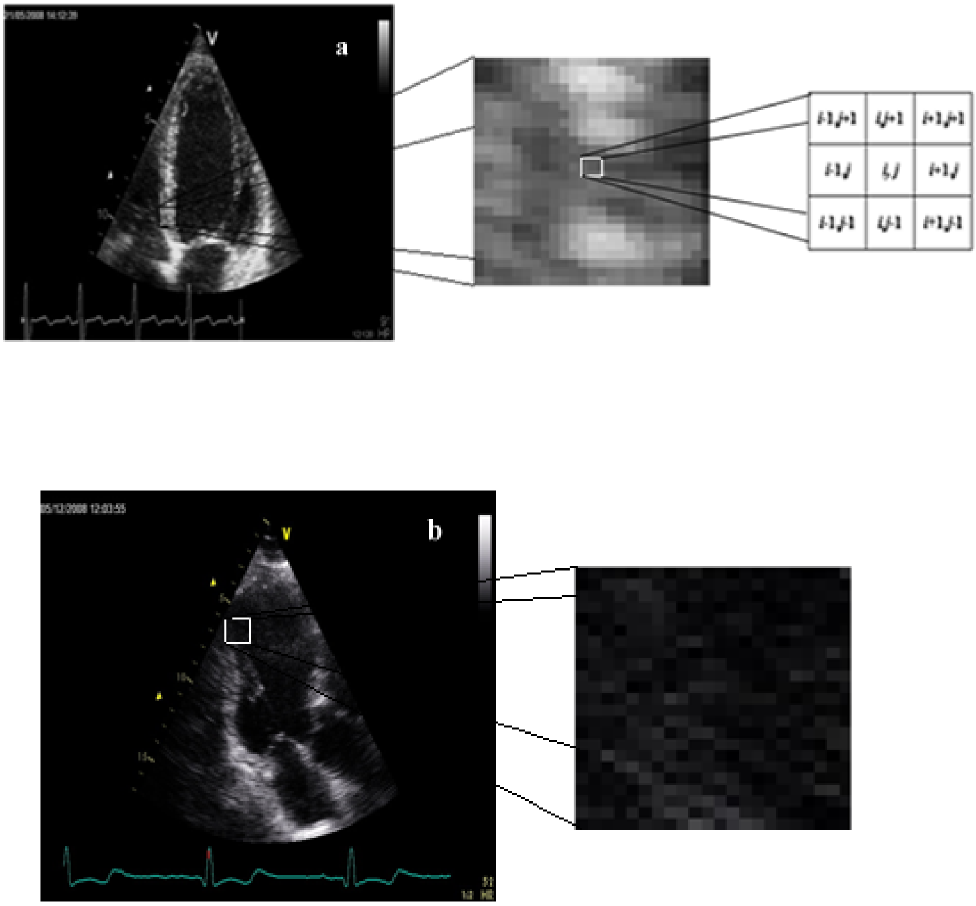

Fig. 1.(a) Apical two chamber (A2C) view of a healthy human patient. A 25x26 pixel region of interest has been cropped from the basal inferior zone. In the right side is the nearest-neighbour resolution cell diagram for texture analysis where (i, j) is the resolution cell coordinates. (b) Apical two chamber (A2C) view of an infarcted human patient. A 25x25 pixel region of interest with infracted myocardium zone has been cropped from the apical inferior zone.

Table 1. Echocardiographic texture results (two camber view) for six patients with infracted heart disease and for six normal subjects

	Healthy myocardium		Myocardial infarction	
	Frame end-diastole	Frame end-systole	Frame end-diastole	Frame end-systole
Mean	90.27 ± 41.56	89.52 ± 39.94	116.19 ± 17.36	109.18 ± 12.15
Standard Deviation	119.13 ± 7.01	120.01 ± 6.61	36.73 ± 7.09	34.76 ± 5.16
Skewness	1.86 ± 0.66	1.76 ± 0.44	1.65 ± 0.12	1.95 ± 0.1
Kurtosis	5.6 ± 2.4	5.17 ± 1.62	4.97 ± 0.65	4.86 ± 0.3
Entropy	6.15 ± 0.56	6.23 ± 0.52	9.12 ± 0.29	9.95 ± 0.17

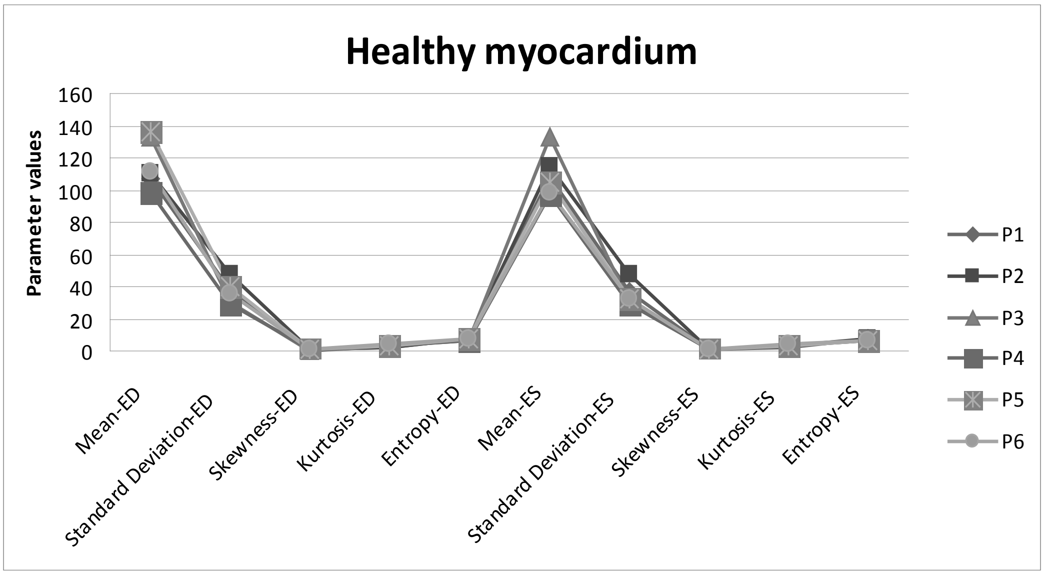

Fig. 2. Evolution of the statistical parameters for healthy patients

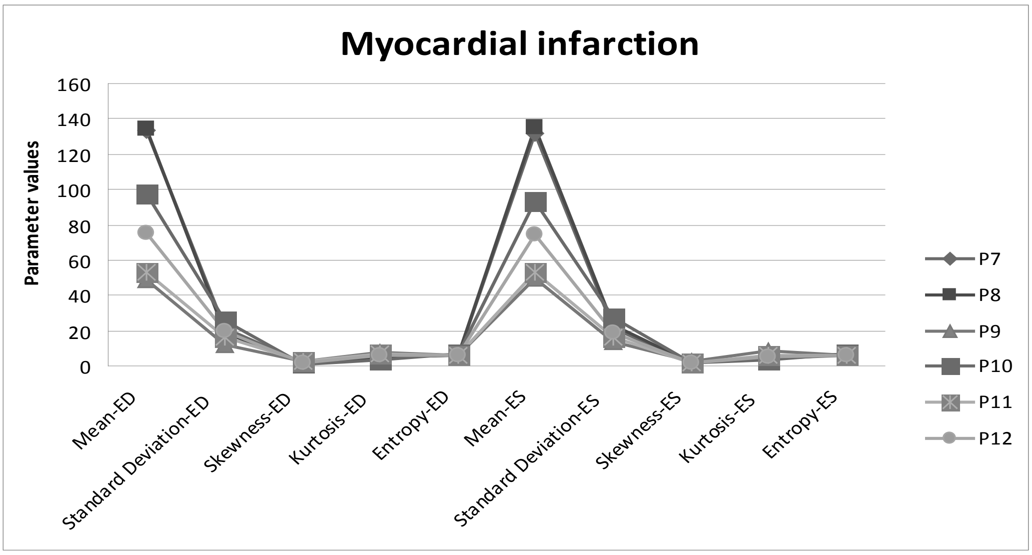

Fig. 3. Evolution of the statistical parameters for patients with myocardial infarction.

4.1 Discussions

Infarcted myocardial echocardiography presents visibly altered values and spatial distribution of the pixels' gray values.

Usually, the first order features allow estimating the properties of the individual pixel value and they also allow the user to avoid the analysis of the spatial interaction between pixels. Moreover these features were used in various studies to highlight the differentiations between normal and abnormal myocardium tissue.

We have employed the whole set (mean gray level, standard deviation, skewness, kurtosis, and entropy) to emphasize the differentiation between normal and infarcted myocardial. The enumerated texture features were calculated in (A2C) view. The results of the present study suggest that some quantitative myocardial textural parameters provide valuable information on clinical outcome of patients with infracted myocardium. These parameters are mean gray value, standard deviation and entropy.

In two chamber A2C view for infracted myocardial tissue, both the mean gray level and entropy show a significant increase and the standard deviation shows a strong decrease. In the infracted myocardium there are fewer scatterers and fewer reflections (because infraction destroys a big number of muscle fibres) but the amplitude of the echoes is higher. The mean describes the average gray value of the distribution and the standard deviation is an expression of the spreading of the distribution from the mean value, namely it characterises the overall contrast of the image. The higher value of the mean parameter represents that the more the gray levels are clustered around the mean value. The strong decreases of the standard deviation parameter highlight the loss in contrast quality of the infracted tissue view. In particular, the entropy allows evaluating the coarseness of the image. Its higher values are in correlation with lower homogeneity of the tissue. This is the biologic explanation for the changes noticed in these parameters.

According to the obtained data in end-diastolic and end-systolic frames shown in Table 1 and the evolution of the statistical parameters from Figures 2 and 3 we can conclude that no significant differences could be found between end-systole and end-diastole frames. Also there are insignificant differences in the skewness and kurtosis parameters. Nevertheless, the differences appear between the subjects of the analysed control group.

Unlike the study accomplished by B. Pinamonti *at al*. [10], that analyzes the differentiation between normal and abnormal (amyloid) myocardium, they concluded that the statistical parameters as entropy and skewness can make a difference between the two patient groups.

We have used the whole set of quantitative parameters in order to determine the salient features that are suitable to difference between normal and infarcted myocardial.

Our findings suggest that the salient feature that can characterize the myocardial tissue is the entropy. This can be explained through the fact that entropy is a measure of randomness of gray level distribution. Usually entropy is expected to be higher if the gray levels are distributed randomly throughout the analyzed samples.

5. Conclusion

This paper deals with the echocardiography texture images analysis and presents the evidence that image texture damages can be quantified using the digital image analysis techniques. We study the problem of feature detection from echocardiography images in an attempt to select those relevant features which are potentially helpful in clinical diagnosis or in any subsequent processing related to biostructural analysis of myocardium.

The samples cropped from A2C in normal and myocardial infarction cases were compared. As a first conclusion, there are no significant differences found for values of the parameters between end-systole and end-diastole frames for each patient. Significant differences exist between parameters computed for normal and myocardial infarction. The salient features that can make a difference between infarcted myocardial and healthy myocardium are entropy, standard deviation and mean. The future works might include a database with first order statistic parameters extracted for a different echocardiopathy and seeks a golden standard of parameters that can characterize a certain disease.

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References

[1] J. Edward, A. Blair, V. H. Rigolin, Echocardiography, Practical Signal and Image Processing in Clinical Cardiology **14** 187 (2010).

[2] M. Schmidt, K. Murphy, G. Fung, R. Rosales, Structure Learning in Random Fields for Heart Motion Abnormality Detection, Computer Vision and Pattern Recognition,. CVPR, IEEE Conference, 2008.
[3] E. M. Ferdeghini, B Pinamonti, E. Picano, F. Lattanzi, R. Bussani , G. Slavich, A. Benassi, F. Camerini, L. Landini, A. L'Abbate, Journal of Clinical Ultrasound **19** (5) 263 (1991).
[4] B. Dagdeviren, O. Akdemirb, M. Eren, O. Bolca, E. Oguza, Y. Gurlertopa, T. Tezela, European Journal of Heart Failure **4**(1) 41 (2002).
[5] V. Punys, J. Puiene, R. Jurkevicius, J. Puinys, Ultrasound Tissue Analysis Based on Texture in Ultrasound Images, Echocardiography **116** 435 (2005).
[6] A. Mojsilovic, M.A. Popovic, A.N.Neskovic, A.D. Popovic, Wavelet Image Extension for Analysis and Classification of Infarct Myocardial Tissue, IEEE Transactions on Biomedical Engineering **44**(9) 856 (1997).
[7] E. Lieback, I. Hardouin, M. Meyer, J. Bellach, R. Hetzer, European Heart Journal **17** 135 (1996).
[8] B. Dagdeviren, O. Akdemirb, M. Eren, O. Bolca, E. Oguza, Y. Gurlertopa, T. Tezela, European Journal of Heart Failure **4**(1) 41 (2002).
[9] C. Marini, E. Picano, A. Varga, P. Marzullo, A. Pingitore and M. Paterni, European Heart Journal **17** 47 (1996).
[10] B. Pinamont, E. Picano, E.M Ferdeghini., J Am Coll Cardiol **14** 666 (1989).
[11] Kahl, L., Orglmeister, R. and Schmailzl, K.J.G., IEEE Ultrasonics Symposium **2** 1173 (1997)
[12] V. Di Bello, O. Giampietro, E .Matteucc, Ultrasonic videodensitometric analysis in type 1 diabetic myocardium, Coron Artery Dis **7** 895 (1996).
[13] A.K. Bandahari, N.C. Navin: Myocardial texture characterization by two-dimensional echocardiography.AmJ Cardiol **51** 817 (1983).
[14] F. Pizzarelli P. Dattolo, E.M. Ferdeghini, M.A. Morales, Parameters derived by ultrasonic myocardial characterization in dialysis patients are associated with mortality, Kidney International **68** pp. 1320 (2005).
[15] O. D. Nurhayati, T. S. Widodo, A. Susanto, M. Tjokronagoro First Order Statistical Feature for Breast Cancer Detection Using Thermal Images , World Academy of Science, Engineering and Technology **70** 1073 (2010).
[16] K.V. Mardia, Measures of multivariate skewnees and kurtosis with applications, Biometrika **57**(3) 519 (1970).