Lodz University of Technology

Faculty of Electrical, Electronic, Computer and Control Engineering

Institute of Electronics

Texture analysis of ultrasound image for evaluation of myocardial viability

LODZ 2019

The evaluation of early post-infarction (MI) myocardial viability is an important component of outcome assessment and long-term risk stratification of heart condition. Myocardial viability is defined as structural integrity enabling the cardiomyocytes to undertake systolic function. Resting echocardiographic examination allows for the identification of preserved contractility of myocardium. However, the heart segments, which are not presenting systolic function at rest may recover or remain non-functional - necrotic. Currently used methods are either utilizing inotropic stimulation (dobutamine) or are not suitable for bedside use (e.g. cardiac magnetic resonance – CMR or positron emission tomography – PET). Additionally, the high cost of CMR or PET makes them available only for a highly selected group of patients. On the contrary, contrast echocardiography is a novel, cost-effective, easy to perform imagining modality that allows the advanced evaluation of myocardial function and viability based on the integrity of microvasculature after the ischemic damage. It is, however, observer-dependent and re-quires additional post-hoc processing and quantification for the accurate and objective assessment. Therefore, an automatic or semi-automatic method suitable for the analysis of contrast echocardiograms, which would enable to evaluate the myocardial viability in terms of echocardiographic texture, would be very useful in the clinical practice.

Progress in computer technology has been tremendous in the last decade, sparkling interest for the potential use of artificial intelligence (AI) in medicine and basic sciences. One of the most interesting and extensively studied branches of AI is the 'Artificial Neural Networks (ANNs). ANNs are a family of statistical learning models used to estimate or approximate functions that can depend on a large number of inputs and are predominantly unknown. Basically, ANNs are mathematical algorithms, generated by computers. ANNs learn from standard data and capture the knowledge contained in the data. They analyze and detect nonlinear relationships between dependent as well as independent variables in the data. ANNs have been extensively applied in diagnosis, electronic signal analysis, medical image analysis and radiology. Ultrasonographic tissue characterization as well as the evaluation of CMR images is a potential application for ANNs

The objective of this work is to present such a texture analysis method, applied for classification of heart tissue with different necrosis degree in contrast echocardiograms. Texture represents properties of visualized objects and provides information about their

structure. It is especially important in transformation of biomedical tissues into images. the second aim is prediction of contractile reserve based on neuronal network analysis of myocardial texture in resting native and contrast-enhanced echocardiographic images. the proposed method is based on the assumption that image texture encodes important histological features of heart tissue and hence texture numerical parameters enable the discrimination of tissues with different myocardial viability.

Ultrasound images suffer from several drawbacks, which impede their automatic analysis. Image information is highly anisotropic and position dependent, since the reflection intensity and signal to noise ratio depend on the depth and the angle of incident ultrasound beam. In addition, there are many artifacts present in echo images, resulting in local loss of anatomical information (shadowing, significant noise dropouts, side-lobes). Thus, analysis of such images is a rather difficult and challenging task.

Sixty-one consecutive patients who were admitted to the Cardiology Department of the Medical University of Lodz with acute coronary syndrome (ACS) with an ST elevation that was confirmed by the coronary angiography occlusion of only one coronary artery were enrolled in our study without regard to their age (43 man, mean age 61 ± 9 years). Within 10h of the onset of symptoms, all of the patients were successfully treated with a percutaneous coronary intervention (PCI) of one of the coronary arteries. For the analysis, we used 588 heart echo images (native or contrast - obtained in myocardial perfusion echocardiography by iv Sonovue injection and Contrast Perfusion Sequence, CPS detection) obtained from the apical window from 61 patients for texture analysis with custom software (MaZDa 4.20). Image texture represents properties of visualized objects and provides information about their structure. It was demonstrated that texture in echocardiograms encodes important histological features of intracardiac masses and hence texture numerical parameters enable the discrimination and segmentation of a given mass [xx]. It was assumed in this study that texture parameters will be also useful in evaluation of myocardial viability. Echocardiographic images were obtained after 7 days (7±1,3 days) with the use of Siemens Sequoia A512 and 4V1c transducer (4-1 MHz). the echocardiographic images with a pixel spatial resolution (as obtained from the ultrasound scanner) were stored as BMP files.

Each patient underwent a CMR study with gadolinium late enhancement imaging to define the % transmurality of necrosis. Linear and non-linear (neuronal network) discriminative

analysis was performed to identify the optimal analytic method correlating with CMR information regarding the necrosis extent. On the basis of the CMR the 6 degree scale was defined for the evaluation of the necrosis of the myocardial muscle.

For regions of interest (ROIs) defined in each image by cardiologist, 298 image texture features were calculated (including those based on histogram, gradient matrix, run length matrix, and co-occurrence matrix, and wavelet transform) using the MaZda software. Six classes of heart tissues with different amount of necrosis were defined. the tissue vitality was evaluated based on MRI examination.

Feature selection was performed in two steps. First, for the selection of parameters which were characterized by the lowest variability, their number was limited to 30 with the lowest standard deviation. In the next stage of selection parameters, there was a further reduction in the number of features using the Fisher criterion, minimizing the misclassification (POE) with an average correlation coefficient (ACC). the method of feature selection POE + ACC is based on minimizing both the probability of misclassification (PoE), as well as the average correlation coefficient (ACC) between the selected parameters.

In order to classify selected features used, neural networks - Multilayer Perceptron (MLP), non-linear discriminant analysis , SVM classifier, Adaboost and Decision Tree Learning approach were used. To determine the optimal method of analysis the results were correlated with information from the CMR concerning the degree of tissue necrosis. the SVM classifier was applied using the LIBSVN for Weka software. LIBSVM supports various types SVM kernel functions for classification. In this study radial basis kernels were used and C-SVC classification type.

Neuronal network approach allowed correct classification regarding the absence of necrosis in 79% of segments and in 84% of images representing different levels of transmurality (≤50% or >50%), based on resting contrast imaging. These results were obtained for a red component of CPS color scale as mean values of 4-fold network cross-validation. A similar feature selection and classification procedure applied for native grayscale images yielded worse results (68% and 79% correct classification for segments and individual images, respectively). Advanced classification of segments into 3 classes: no necrosis (80% of regions)/

1-50% necrosis (5%) / >50% necrosis by MRI (15%) was 70% correct for CPS and 60% correct for native images. All classifiers provided similar results.

Neural networks were effective in predicting LV function after one year. It was demonstrated that texture analysis applied to echocardiograms can predict ventricular function and remodeling after one year. Performance of SVM, MLP and AdaBoost as well as native vs CPS images was similar. Best accuracy was obtained for predicting WMSI improvement (77 79%).

It was observed that texture parameters of tissue derived from both monochrome and red component of color ultrasonography images are important for heart regions classification. Other components (green and blue) of color RGB images were not useful for discrimination. This is probably linked with nonlinear mapping of gray levels onto colors performed by Siemens electrocardiograph, unfortunately the manufacturer does not provide any information on this issue.

Results indicate that neuronal network based texture analysis of echocardiogram provide useful data on myocardial viability early after MI without need for stress testing. It was confirmed that myocardial contrast enhancement allows a superior classification of necrotic tissue as compared to native grayscale images. Selected texture features, mainly related to entropy measures are thus useful for early post-MI detection of myocardial necrosis. ANNs have a big potential means for creation of advanced prognostic tools in cardiovascular disease even using standard or contrast-enhanced echocardiographic imaging.