Leveraging Radon Descriptors and Machine Learning to Anticipate Left Ventricular Endocardial Scar Tissue Patterns

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Abstract: Scar tissue in the left ventricular (LV) endocardium is a critical factor in the development of malignant ventricular arrhythmias and potentially fatal cardiac outcomes in myocardial infarction patients. This study aimed to assess LV endocardial scar tissue patterns using a Radon descriptor-based machine learning approach. Automated LV segmentation and morphological operations were performed to identify scar tissue regions on the endocardial wall. CT images from 17 patients were used to extract patches categorized as "endocardial scar tissue" or "normal tissue." Ten feature vectors were extracted from each patch using Radon descriptors and fed into a traditional machine learning model. The decision tree model achieved a remarkable accuracy of 98.07%. This study represents the first application of Radon transform-based machine learning for differentiating endocardial scar tissue patterns, with potential implications for advanced interventions. Overall, our findings demonstrate the efficacy of this approach in predicting and analyzing LV endocardial scar tissue, offering potential improvements in myocardial infarction patient care.

Keywords: Heart, Left ventricular, Radon, Machine learning.

1. Introduction

Scar tissue formation in myocardial infarction patients can lead to severe consequences, including ventricular arrhythmia. The prevalence of cardiovascular disease is expected to rise significantly, emphasizing the need for effective strategies to assess and understand scar tissue development. Left ventricular (LV) remodeling is a crucial aspect to consider, as it impacts the pump function and overall prognosis of patients following a myocardial infarction. However, designing effective therapies requires a comprehensive understanding of scar formation, its properties, and its impact on cardiac mechanics and electrical conduction [1, 2].

While previous studies have focused on scar detection using CMR imaging, our approach utilizes CT modalities due to their accessibility and faster scanning capabilities. CT scans collect X-rays from various angles to generate images, providing a viable alternative for scar tissue analysis. In this study, we present a novel approach that bridges the gap between Radon descriptors and machine learning algorithms to accurately identify patterns of normal and scar tissue in the LV endocardium [3].

The paper is structured as follows: the Method section outlines the imaging data used, summarizes our approach, and describes the steps taken. The Results section presents the findings, followed by a comprehensive discussion, and finally, the study's conclusion. By employing this innovative strategy, we aim to contribute to the advancement of scar tissue assessment and the development of potential therapeutic interventions for myocardial infarction patients.

2. Methods

Data Acquisition and Automatic Segmentation of LV:
The study utilized a Philips computerized tomography (CT) device to acquire cardiac CT images from 17 male and female patients with A-fib, aged 50-62. The CT device captured ten sets of timed frames, including a whole cardiac cycle, resulting in a dataset of 409 images with a resolution of 512x512 pixels. Delayed enhancement CT images were selected for analysis, and irrelevant layers were omitted,

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resulting in a dataset of 149 CT images specifically displaying the left ventricular (LV) portion. The study was conducted in accordance with the Institutional Review Board of National Yang-Ming University Hospital, and informed consent was obtained. The LV segmentation was performed automatically using the Segment CT software, which allowed for the identification of the LV on short-axis stacks by placing points during the reconstruction process. To determine the presence of scar tissue in the dataset, standard deviation (SD) and average pixel value calculations were employed based on the concept that scar tissue is characterized by three SD values greater than the average intensity value of a healthy myocardium region [4, 5].

Implementation of Morphological Operations and Patch Creation:

Fundamental morphological operators such as erosion, dilation, opening, and closing were applied in this step to extract relevant information. The criteria were set such that pixel values considered as contrast areas in the specific dataset needed to be higher than two SD values and one average value, enabling clear identification of contrast areas. Twenty-five patches, each with dimensions of 25x25, containing the scar region on the LV, as well as normal tissue/non-scar tissue, were extracted [4].

Radon Descriptor and Texture Feature Extraction:

Content-based image retrieval (CBIR) involves examining and retrieving image content based on various criteria such as color, shape, and texture. The Radon transform, an integral transform, was employed in this study to describe the visual characteristics of medical images and aid in CBIR applications. Radon descriptors were created for each patient by generating Radon images from the extracted patches using the MATLAB R2018a platform. Texture features were extracted from the Radon images using the local binary pattern (LBP) approach, which transforms an image into an array or image of integer labels representing its appearance at small scales. These numerical feature data were then fed into conventional machine learning models for further analysis, including face detection and pattern recognition [6, 7, 8].

Overall, the methodology involved data acquisition, automatic LV segmentation, morphological operations, patch creation, Radon descriptor generation, and texture feature extraction.

3. Results and Discussion

In this study, our aim was to develop an automated method for predicting the pattern of endocardial scar tissue on the left ventricular (LV) myocardial wall. Scar tissue has a significant impact on LV function and remodeling. We computed the average pixel value and standard deviation (SD) of the myocardium wall for each slice in the dataset, which yielded an average of 58.77 and an SD of 20.75. This step was crucial in our analysis. Using the region growing algorithm on the dataset, we calculated the average, SD, and number of pixels in the growing area, specifically the LV myocardium wall. The obtained values for the entire population were 59.89 and 21.2, respectively, which matched the findings of previous studies, validating our analysis.
Next, we applied an image processing morphological algorithm, involving erosion, dilation, closing, and opening operations. By considering the threshold value of the intensity mean, we transformed the image into binary form, revealing black and white spots. White spots represented areas of higher intensity and greater contrast. We identified locations with higher pixel values, indicating the presence of scar tissues. All endocardial scar tissue and normal patches were used to generate Radon descriptor images for machine learning. Numerical data of features were extracted, and the dissimilarity distance between normal and scar tissue patterns was calculated, resulting in a value of 9.05. This data was then inputted into traditional supervised learning models, including Decision Tree, SVM, and Logistic Regression, for fast prediction of scar tissue and normal/non-scar tissue patterns. The models were evaluated using a 5-fold cross-validation, considering parameters such as sensitivity, specificity, and accuracy. Among the classifiers, the Decision Tree algorithm exhibited the most promising results, with a specificity of 95.07%, sensitivity of 96.08%, and accuracy of 98.07%. However, SVM and Logistic Regression did not perform as well in this context. These findings demonstrate the potential of our developed model for predicting endocardial scar tissue patterns and highlight the effectiveness of the Decision Tree algorithm in this application.

Author Statement

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Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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