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Automatic cardiac T2* relaxation time estimation from magnetic resonance images using region growing method with automatically initialized seed points

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ABSTRACT

Background and objective: Heart failure due to iron-overload cardiomyopathy is one of the main causes of mortality. The cardiomyopathy is reversible if intensive iron chelation treatment is done in time, but the diagnosis is often delayed because the cardiac iron deposition is unpredictable and the symptoms are lately detected. There are many ways to assess iron-overload. However, the widely used and approved method is by using MRI which is performed by calculating the T2* (T2-star). In order to compute the T2* value, the region of interest (ROI) is manually selected by an expert which may require considerable time and skills. The aim of this work is hence to develop the cardiac T2* measurement by using region growing algorithm for automatically segmenting the ROI in cardiac MR images. Mathematical morphologies are also used to reduce some errors.

Methods: Thirty MR images with free-breathing and respiratory-trigger technique were used in this work. The segmentation algorithm yields good results when compared with the manual segmentation performed by two experts.

Results: The averages of positive predictive value, the sensitivity, the Hausdorff distance, and the Dice similarity coefficient are 0.76, 0.84, 7.78 pixels, and 0.80 when compared with the two experts' opinions. The T2* values were carried out based on the automatically

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segmented ROI's. The mean difference of T2* values between the proposed technique and the experts' opinion is about 1.40 ms.
Conclusions: The results demonstrate the accuracy of the proposed method in T2* value estimation. Some previous methods were implemented for comparisons. The results show that the proposed method yields better segmentation and T2* value estimation performances.

1. Introduction

Regularly blood transfusion is required for a treatment of thalassemia major patients. Multiple blood transfusions may lead to a significant risk of heart disease due to iron overload [1,2]. Several methods have been employed for tissue iron-overloaded assessment such as serum ferritin, liver iron concentration (LIC), superconducting quantum interface device (SQUID), and magnetic resonance imaging (MRI). LIC is the most reliable method but is invasive technique which requires liver biopsy. Due to the invasiveness of LIC approach, infection is likely to occur [3,4].

Serum ferritin, SQUID, and MRI are non-invasive techniques. Serum ferritin requires a number of examinations in order to follow-up the symptom. SQUID needs an operator, yet the machine is in short supply. It can quantify iron concentration in liver and heart by investigating some parameters such as the relaxation time constant (T2*) and relaxation rates (R2*). The T2* is a relaxation parameter arising principally from local magnetic field inhomogeneities which decreases as a result of iron concentration in some internal organs (liver and heart) while the R2* is a reciprocal of T2* (1/T2*). Patients with small T2* (<20 ms) which corresponds to myocardial iron loading, have significantly higher risk of resting systolic dysfunction and require more treatments than patients with T2* values in the normal range (>20 ms) [3–5].

Westwood et al. [6] proposed a method to compare the measurements of cardiac T2* between the established multiple breath-hold variable TR technique with a multiecho sequence that acquires all images within a single breath-hold with a constant TR. The experimental results showed that the single breath-hold, multiecho acquisition method allowed reliable quantification of cardiac T2*, good reproducibility and speed, greater accuracy, faster patient throughput, and reduced costs. The comparison between T2* calculation from different data acquisition techniques, black-blood and white-blood techniques, were proposed [7–11]. The results showed that black-blood technique gave better reproducibility than the white-blood technique.

Selection of a curve-fitting model is another concern to the accuracy of the T2*. Three models are used to fit the T2* decay including mono-exponential, bi-exponential, and offset models. Some previous works also proposed the truncation model which discarded the late plateau points, the complicated points due to noise and motion which make errors for evaluating the T2*, and then fitted the remaining points with a mono-exponential model. This model helps in reducing the problem of heavily iron-loaded hearts which has very small T2* (<10 ms) resulting in a rapid decay in signal intensity (SI), and leading to the low signal-to-noise ratio (SNR) in the later echo time (*TE*) images [8,9,11–14].

In order to compute the T2* value, a region of interest (ROI) is manually selected by an expert which is a time consuming task. Hence, the automatic segmentation algorithm is used to solve this problem. There are two methods for the ROI selection in cardiac MR images, i.e., region-based method and pixel-wise method. Previous studies showed that the resulting T2* values from the two methods were similar but the pixel-wise method needed more computation. So the region-based method is suitable for the system which needs rapidity [8,9,13,15]. There are several works that tried to segment LV and analyze the endocardial and epicardial contours automatically. Many semi and fully automatic algorithms have been proposed [16–32]. In 2011, there was a survey paper which proposed the segmentation methods in short axis cardiac MR images. It separates the medical image segmentation into two main groups, i.e., segmentation with weak or no prior (no training datasets are needed) and segmentation with strong prior (need some datasets to train the system) [19].

The example of segmentation methods and their improved method or hybrid method between them are thresholding [15,18], region growing [20], dynamic programing (DP) [21], deformable models [22], active contour models (ACM) [17,23,24], level-set [25], graph cuts [22], KNN classifier [26], convex relaxed distribution matching [27], edge modeling [28,29], and clustering [30]. Most of the automatic LV segmentation works were applied to calculate the cardiac function such as stroke volume (SV), mass or ejection fraction (EF) whereas only few work focused on T2* evaluation.

Semi-automatic T2* assessment involving cardiac MRI was proposed. However, the ROI's were manually segmented by a user for the T2* calculation [31]. Fully automatic myocardial T2* measurement has been proposed [32]. The epicardium and endocardium was located by using circular Hough transform (CHT) followed by the improved Chan–Vese (I-CV) model to extract myocardial. After that, the right ventricle (RV) was segmented by using the thresholding method in which the threshold value was automatically calculated from the segmented LV. Finally the interventricular septum was analyzed by using the geometrical relation between myocardium and RV. The experimental results showed the comparison between T2* measurements using the proposed method and manual method by an expert.

The aim of this work is to develop a fully automatic cardiac T2* assessment method by using region growing algorithm and mathematical morphologies for segmenting the myocardium in cardiac MR images without any human intervention. This means the proposed method does not require any manual processes during the ROI segmentation and T2*