Non-Local Means Denoising for Myocardial T2* Measurement
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Introduction: Myocardial T2* measurement is a valuable tool for non-invasive assessment of tissue iron overload which can prevent disease in thalassemia patients (1). For the heavily iron loaded heart, T2* is substantially shortened (<10ms) and the signal to noise ratios (SNRs) of later echo images are usually very low (2). Various signal processing techniques have been proposed for denoising MRI images with varied levels of success, but also criticised for smoothed image details. Waveatom technique, which has the ability to adapt to arbitrary local directions of a pattern, demonstrated advantages over wavelet in reducing MRI noise (3). A more recent development is a non-local means (NLM) method (4), which has shown great potential in dealing with MRI noise (4). To be useful in clinical settings, a denoising algorithm must preserve fine details of the original images and should not alter the diagnostic information extracted from the images. By comparing these two techniques on myocardial T2* images from patient with cardiac overload, the purpose of this study was to evaluate denoising effects on T2* images and quantification using state-of-art signal processing techniques.

Methods: An ECG-triggered multi-echo gradient echo sequence was implemented on a 1.5T MR scanner (Sonata, Siemens AG). In total, data from 10 thalassemia patients with severe cardiac iron (T2*<10ms) were retrospective processed using both the waveatom and the NLM techniques. The Waveatom and the NLM algorithms were programmed in Matlab. Standard deviation of the noise (σ) was measured in the background area with void signal. The searching and similarity windows were optimized for the NLM algorithm. The threshold of the waveatom algorithm was set as 3σ. For T2* measurement, a region of interest (ROI) was drawn in the left ventricular septum and the truncation model was implemented (2) using CMRTools:ThalassaemiaTools®. The image quality of the original and denoised data was assessed by an experienced cardiologist. ANOVA was used for comparison of multiple groups of T2* measurement. A p value of 0.05 was considered as statistically significant.

Results: Figure 1 shows a typical set of example images: the original image and the denoised ones using waveatom and NLM algorithms. The waveatom denoised image appears cleaner compared with the original image. The NLM algorithm, however, removed the most of the noise while preserved the fine details, which can be further explained in zoomed images in Figure 2. Looking at the top row of Figure 2, the background noise was well suppressed with the NLM algorithm while new unexpected noise pattern was introduced by the Waveatom algorithm. Fine details were well preserved with the NLM algorithm, but blurred with the waveatom method (Figure 2, middle and bottom rows). The image quality of NLM denoised data was rated best by the experienced clinician. There is no difference (p > 0.5) regarding T2* measurements based on the original and the two set of denoised data. Figure 3 are example images showing ROI drawing and very close T2* measurements obtained from the original and the denoised data.

Conclusions: Contrast to previous reports, the performance of the waveatom algorithm is not satisfactory because it introduces additional method noise and blurs details. The NLM algorithm, however, demonstrates great ability to remove noise while preserving fine details of the myocardial T2* images, which is of great clinical interest. In addition, the diagnostic information (T2* measurement) was not affected by the denoising algorithm. These preliminary results are encouraging and a future study is warranted to explore the potential of the novel NLM method for better MRI images with improved T2* measurement. This method can also be used in other scenarios such as myocardial perfusion and late enhancement where SNR has been a challenge.

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References: