Noise suppression in black-blood STEAM cardiac imaging

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Introduction: It has been shown recently that adding two STEAM cine sequences, $I_1(t)$ and $I_2(t)$, that are acquired with two different demodulation gradients yields quality black-blood cine sequence of the heart [1]. Although the resulting sequence does not suffer from the deformation-related artifacts that are usually encountered in the generic STEAM sequences, the addition of the two sequences enhances the image noise. Noise suppression in the individual images $I_1(t)$ and $I_2(t)$ using intensity thresholding is not proper because of the inherent low SNR in STEAM sequences. In this abstract, information extracted from the joint histogram of the two sequences is used to suppress the background noise in the resulting sequence.

Purpose: Developing a method to suppress the background noise in STEAM cardiac cine images in order to enhance the myocardium-to-blood contrast.

Theory: At time frame t, the pixel intensity in $I_1(t)$ and $I_2(t)$ is inversely and directly proportional to the level of the tissue deformation respectively (Fahmy et al [1]). That is, static tissues appear bright in $I_1(t)$ and dark in $I_2(t)$ while highly contracting tissues appear bright in $I_2(t)$ and dark in $I_1(t)$. On the other hand, the background regions (blood and air) appear as noise (dark/black regions) in both images. Therefore, observing the pixel intensity in both images can be used to determine whether a pixel belongs to a background or tissue regions. The joint histogram of $I_1(t)$ and $I_2(t)$ is shown in figure 1.a where the noise pixels occupy the low intensity corner (region R1) and thus can be isolated and suppressed from the other image pixels. This can be done by using the following equation: $I(x,y,t) = W(I_1(x,y,t), I_2(x,y,t)) \cdot (I_1(x,y,t) + I_2(x,y,t))$. Where $I(.)$ is the filtered black-blood cine sequence and $W(.)$ is intensity weighting function (see Fig. 1.b) that can be determined from the intensity distribution of the joint histogram.

Results and discussion: Figure 2 shows five time frames of the black blood sequence before and after noise suppression (first and second row respectively). The images were obtained using 3.0T scanner (Philips medical systems). It can be seen that the proposed method was successful in suppressing the background noise and thus increasing the contrast-to-noise ratio of the images.

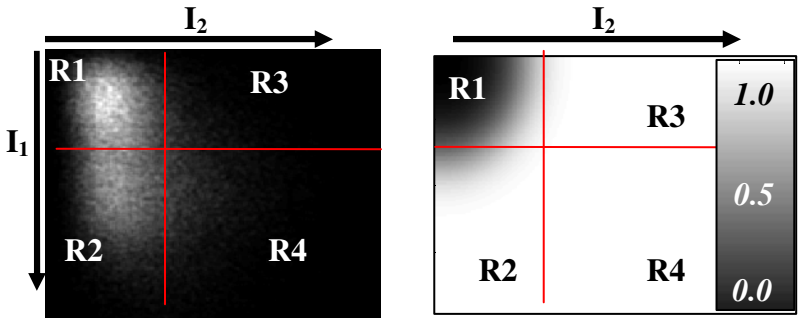

Figure 1. (a) Joint histogram of I_1 and I_2. Region R1 represents the noise where the intensity is low in both images. (b) The weighting function $W(I_1, I_2)$. Notice that the function is zero at the noise region R1 and increases at the other regions

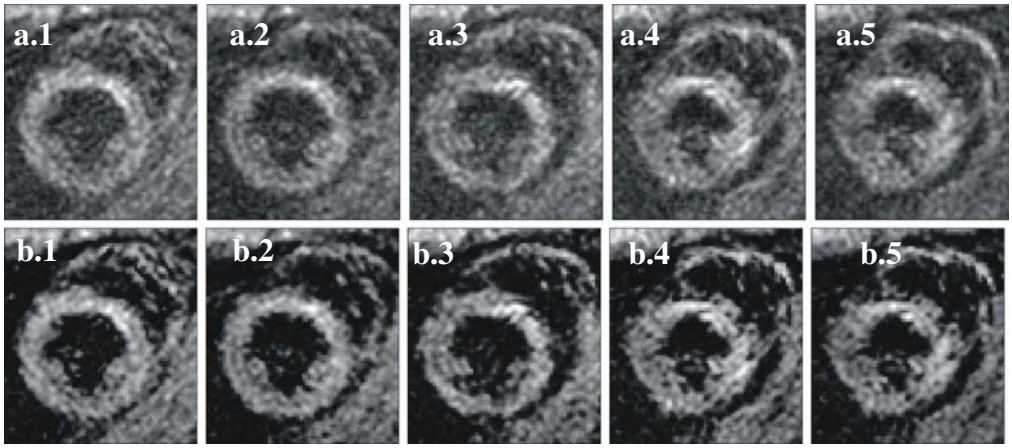

Figure 2. Five time frames of a black blood sequence acquired with the modified STEAM pulse sequence (a.1-5) before and (b.1-5) after denoising.

References: [1] Fahmy et al. MRM, 2006 Feb;55(2):404-12.