Automatic detection of systolic and diastolic phase for NATIVE

A. Stemmer[1], P. Schmitt[1], and B. Kiefer[1]
[1]Siemens Medical Solutions, Erlangen, Germany

Introduction: NATIVE is a non-contrast-enhanced peripheral MRA technique, which acquires two 3D turbo spin echo (TSE) data sets in different cardiac phases. The first data set is acquired during slow flow in arteries and veins (diastolic phase), depicting both vessel types as bright blood. The second data set is acquired during fast flow in arteries (systolic phase) showing black-blood arteries and bright-blood veins. Artery only images are obtained by subtracting images from the two data sets [1]. The correct diastolic and systolic timing is crucial. Optimal trigger times (TT) can be determined in a TT-scout scan. The TT-scout scan acquires a single shot TSE image of the vessel multiple times with increasing trigger time. The operator views the TT-scout images and finds a first image, which depicts arteries and veins and a second image, which suppresses arteries. The operator then applies the TT times associated with the selected images in the first and second 3D scan, respectively [2]. In this abstract we will discuss a technique which automatically detects optimal TT times from the TT scout images by means of image processing methods.

Methods: NATIVE was implemented in a 3D-HASTE sequence. The HASTE sequence encodes all phase-encoding lines of the k_y direction along a single echo train. The amplitude of the phase encoding gradient along k_z is the same for all echoes of an echo train. Echo trains are repeated to encode k_z. During the TT scout phase the echo train with k_z =0 is acquired multiple times with increasing TT time. From the data of each scout scan a two dimensional projection image $I_i(x,y)$ of the 3D slab is calculated. The index labels the number of the scout scan ($i=1,\dots,N_s$) and is associated with a particular TT time TT_i. The processing of the scout images includes the following steps:

1. Each projection image is cropped to exclude peripheral pixels in head-feet direction from the following steps
2. From each projection image all other projection images are subtracted: $S_{i,j}(x,y)=I_i(x,y)-I_j(x,y)$. The output of this step is $N_s x(N_s-1)$ subtraction images. Each subtraction image inherits a diastolic TT time TT_i from its minuend and a systolic TT time from its subtrahend TT_j.
3. Each subtraction image is subjected to a vessel segmentation algorithm. The output of the vessel segment algorithm is a mask image $M_{i,j}(x,y)$. The mask image is equal to 1 at pixel positions classified as "artery" and equal to -1 at each pixel position classified as "background".
4. For each subtraction image a quality criterion $Q_{i,j}$ is calculated that reflects the depiction of arteries. Here the mean intensity difference between pixels qualified as artery and those qualified as background is used:
   $Q_{i,j} = \sum_x \sum_y \delta[M_{i,j}(x,y)-1] S_{i,j}(x,y) \Big/ \sum_x \sum_y \delta[M_{i,j}(x,y)-1] - \sum_x \sum_y \delta[M_{i,j}(x,y)+1] S_{i,j}(x,y) \Big/ \sum_x \sum_y \delta[M_{i,j}(x,y)+1]$. $\delta[n]$ is the Kronecker delta.
5. The subtraction image which maximizes the quality criterion is selected and the associated diastolic/systolic trigger time is applied during the first and second 3D scan, respectively.

In step 4. Hysteresis thresholding [3] was used. Hysteresis thresholding is a segmentation algorithm, which uses the fact that pixels, which belong to a particular artery, are connected. The algorithm sweeps through all pixels of the image. Any pixel with intensity greater than a threshold TH1 is considered as a seed of an artery. The seed pixel and all pixels with intensity greater than a second threshold TH2 (TH2<TH1), which are connected to the seed pixel directly or via other pixels having intensity greater than TH2 are classified as artery. To set the threshold parameters TH1 and TH2 prior knowledge about size and orientation of the arteries is used.

Results and conclusion: At the time of submission, the method has been tested in volunteers, but not yet in patients. Fig. 1a shows a result of the TT scout scan. The subtraction image, which received the highest score is displayed together with the associated TT times in the Online display. The operator reads the displayed TT times and applies them in the first and second 3D scan, respectively. The subtraction image allows verification of the result. The result is reliable if the subtraction image shows arteries as bright blood. Once the robustness of the method has been proven in a larger patient population the TT scout scan can be incorporated in the 3D scan and the application of the result times can be done automatically. For comparison, Figs 1b and 1c show the original projection images. In the original images it is difficult for an inexperienced operator to identify the different signal intensities in the descending aorta.

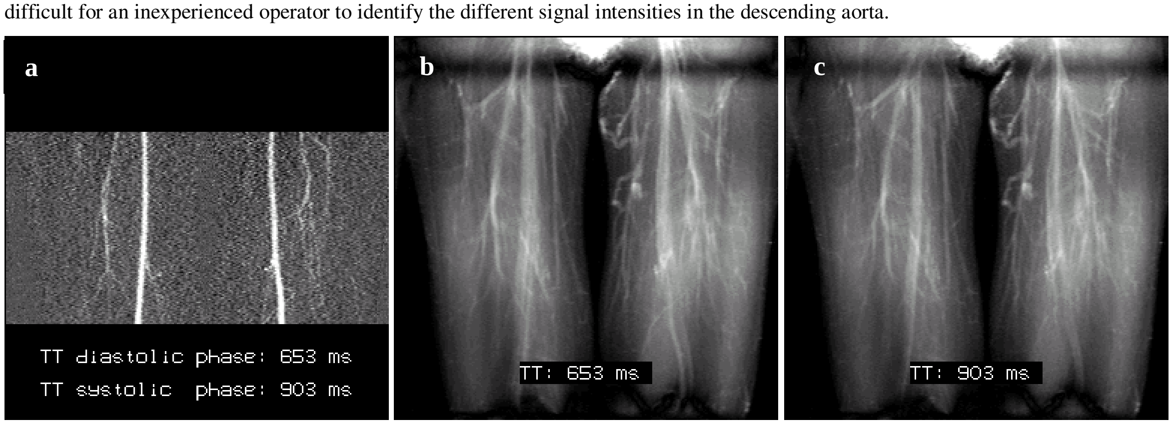

Fig. 1: *a. Result image of the new method; b and c. Two out of N_s=20 result images of the original method*

References:
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[2] M. Miyazaki et al. JMRI 12:776-783 (2000)
[3] J. Canny IEEE PAMI-8, no. 6 679-698 (1986)