Automatic Selection of Mask and Arterial Phase Images for Temporally-Resolved MR Digital Subtraction Angiography

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Introduction

Previously it was demonstrated that linear filtering of dynamic contrast-enhanced MRA images using a manual procedure generates a convenient summary arteriogram of high SNR and greater vascular details. For time-resolved background-subtracted contrast-enhanced magnetic resonance angiography, the bright and sparse arterial signal allows unique identification of contrast bolus arrival in the arteries. We present an automatic filtering algorithm using such arterial characterization for selecting arterial phase images and mask images to generate an optimal summary arteriogram.

METHODS

Linear Filtering selects a mask image set and an arterial phase image set to generate a linear filtered image. For a given time series of N images $\{I_n(x,y),\ n\in[1:N]\}$, we want to select the mask image set (M) and the arterial phase image set (A), such that "best quality" is achieved for the subtracted or filtered image,. $S(x,y) = \sum_{n\in A} I_n(x,y)/|A| - \sum_{n\in M} I_n(x,y)/|M|$. Previously, this filtering was done manually. Here we introduce an image quality function that allows automatic filtering.

Image Quality Fucntion $Q(I)$ reflects the quality of a given gray image I. Two basic desiderata of a general image are: i) Foreground should be as bright as possible; ii) Background should be as dark as possible. Our choice of $Q(I)$ is:

$$Q(I) = \sum_{y\in[yinit:ystep:yfinal]} \left(\frac{\sum_{p\in ISort([1:MinWidth],y)} I(p)}{MinWidth} - \frac{\sum_{p\in ISort([MaxWidth+1:256],y)} I(p)}{256-MaxWidth} \right)$$

where $ISort([1:256],\ y)$ is the sorted array of $I([1:256],\ y)$ in descending order for each y (See Figure 1).

Selection Algorithm for the set of mask images (M) and the set of arterial phase images (A) consists the following 7 steps:

1. Detect the contrast arrival time (N_{ca}) using a voting method. (See Figure 2)
2. Select the best single mask and arterial phase image pair of the highest $Q(S)$ from $[1:N_{ca}-1]$, $[N_{ca}-1:N]$.
3. Initialize M & A with the best mask and arterial phase images selected in step 2.
4. Update A by adding other arterial images that increase $Q(S)$ with current M.
5. Update M by adding other mask images that increase $Q(S)$ with current A.
6. Repeat steps 4 & 5 until convergence.

Materials and Methods. Forty-five patients underwent dynamic contrast enhanced 2D projection MRA of the calf were used for linear filtering using both the manual image selection and the automatic algorithm. The time resolved image set consisted of 35 images acquired 1.95 seconds per image. Two radiologists, blinded to the filtering process, accessed the automatically and manually filtered image pair presented in an randomized order.

RESULTS

In the image quality comparison, both readers rated the automatic filtering and the manual filtering similarly with no significant statistical difference (See Table 1). Figure 3 is an example in which the automatic filtered image gave substantially better suppression of background noise compared to the manually filtered image.

DISCUSSION

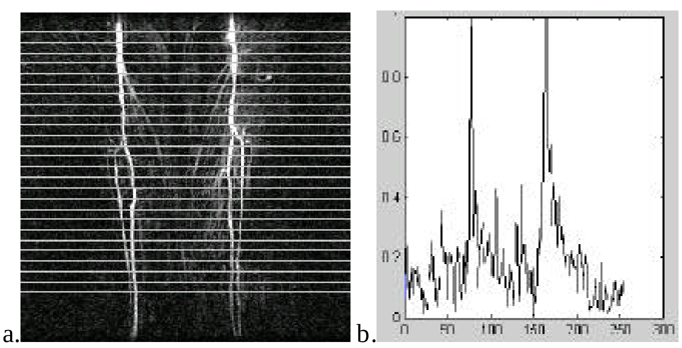
The clinical data from 45 patients in this study demonstrate that the proposed automatic algorithm for selecting optimal mask images and arterial phase images to generate a linear filtered image works as well as the manual procedure. This automatic image filtering technique is simple and can be easily used in routine clinical practice to process dynamic background-subtracted contrast enhanced MRA data.

REFERENCES

1. Prince MR et al. Int'l workshop on MRA, 84, 2001

Table 1. Image quality comparison results on the five scales (the automatically filtered image is substantially worse [-2], modestly worse [-1], approximately the same [0], modestly better [1], substantially better [2] than the manually filtered image).

	Manual vs. Automatic					
Image Quality	-2	-1	0	1	2	p value
Radiologist 1	4	11	2	25	3	0.1533
Radiologist 2	5	17	9	11	3	0.2043



a. b.

Fig.1. Image quality evaluation. (a) Set of scan lines with $y_{init} = 17$, $y_{final} = 224$, and $y_{step} = 4$. (b) Intensity profile of a scan line.

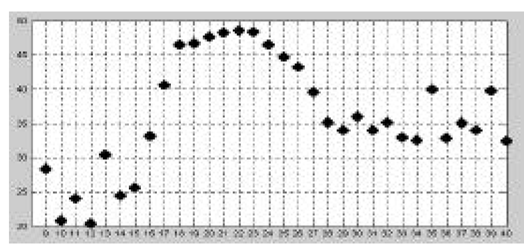
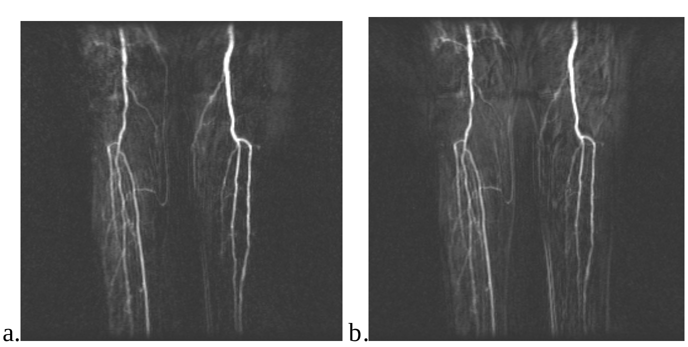


Fig. 2. Contrast Arrival Detection. Plot of $Q(S)$ versus the image index. Notice that a sharp increase of $Q(S)$ corresponds to the contrast arrival.



a. b.

Fig.3. Coronal 2D MRDSA, (a) Automatic filtering (b) Manual filtering.