# MR Myocardial Perfusion Parametric Maps: Preservation of Spatial Resolution with Noise Suppression

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**Introduction**

Due to the requirements for rapid imaging on the order of 100-150 ms per image required for MR myocardial perfusion imaging, the resulting images are compromised by low SNR and relatively poor spatial resolution relative to the size of potential ischemic regions. To assist in semi-quantitative evaluation of the images, parameters related to myocardial blood flow such as upslope, peak intensity, and area under the curve are often calculated. Several groups have proposed methods for parametric map generation of perfusion-related parameters [1]. The purpose of this study was to evaluate approaches to parametric image generation that (1) preserve spatial resolution to facilitate detection of small ischemic areas, and (2) require minimal user interaction to produce a reliable result.

**Methods:** Analysis of myocardial perfusion from dynamic Gd-DTPA-enhanced imaging can be divided into several steps (1) preprocessing of the images including registration, (2) coil correction of intensity variation, (3) determination of relevant timing landmarks such as start and end of the baseline, foot and peak of tissue time-intensity curves, and (4) calculation of parametric maps. After evaluation of both temporal and spatial filtering methods and their effect on timing landmark identification, and quality of resulting parametric maps (as shown in Figures 1 and 2), we applied the following steps to generation of the maps: (1) registration of the images using an algorithm with subpixel resolution [2] and optional user correction (Argus, Siemens), (2) linear coil correction using a region of interest defined by the epicardial border of the left ventricle, based on images obtained pre-contrast arrival, (3) semi-automatic determination of the arrival of contrast (foot), and peak of the contrast-enhancement in the myocardium (averaged over a ring of seedpoints placed in the myocardium, each seedpoint defining a 3x3 pixel region), defined as $t_{foot\text{-}avg}$ and $t_{peak\text{-}avg}$, (4) use of the average foot and peak to derive parametric maps of slope (average slope from $t_{foot\text{-}avg}$ and $t_{peak\text{-}avg}$), area under curve from $t_{foot\text{-}avg}$ and $t_{peak\text{-}avg}$, and signal intensity at $t_{peak\text{-}avg}$.

Images from 7 patients with known coronary artery disease were evaluated. Typical imaging parameters were as follows: saturation recovery TurboFLASH, matrix 192x109, reconstructed resolution 1.9 x 1.9 mm, slice thickness 8 mm, flip angle 16, 3 images per heartbeat in diastole (acquisition window 190-220 ms), for 60 heartbeats. Images were obtained during breath hold to minimize respiratory motion. In detail, to evaluate the effects of spatial filtering on the results, keeping in mind the requirement to preserve spatial resolution, we evaluated a Gaussian filter with window sizes 1,3,5, and 7x7 pixels on the resulting parametric maps. For determination of the temporal landmarks in the images, we evaluated the effects of temporal filtering to reduce noise in the pixel based signal intensity time curves using a temporal averaging filter with window sizes 1,3,5 and 7 timesteps. Based on initial results with a temporal filter with window 5, an algorithm was developed to identify the peak and foot automatically, and was compared to manual definition of the foot and peak points for each pixel in a defined region of interest. SNR of each parametric map was calculated as was the CNR between normal and ischemic myocardium for each study and each processing method as an initial indicator of quality.

**Results**

Although spatial filtering improves image SNR, the risk of partial volume effects due to mixed blood and myocardial voxels was high, and therefore no spatial filtering was used. Temporal filtering improved the automatic determination of both contrast arrival (foot) and peak signal intensity, but for regions with low SNR or voxels with mixed tissue (blood and myocardium), the automatic analysis was not reliable (30 – 50% accurate as compared to manual selection of foot and peak for each pixel). Even manual determination of the foot and peak was difficult in these regions and required comparison with curves from regions with high SNR. Even so, manual selection resulted in relatively noisy parametric maps. Therefore, to reduce noise caused by variations in selection of peak and foot times in neighboring pixels, we evaluated the alternate scheme of deriving parametric maps based on average foot and peak times. Table 1 shows a comparison of CNR and SNR for the various processing methods for all parameters. Slope and peak signal intensity benefitted more from filtering than did the area parameter as expected.

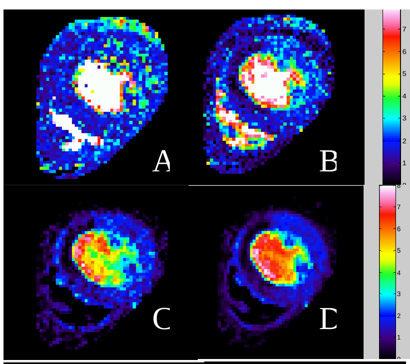


Figure 1a shows the slope parametric map with spatial filtering and resultant loss of discrimination between normal and ischemic myocardium. Figure 1b shows the same dataset with temporal filter window 5, no spatial filtering, and use of manually determined foot and peak values showing better discrimination but more noise. Figure 1c shows the same dataset with use of the average foot and peak timepoints showing improvement in SNR while preserving spatial discrimination (no temporal filtering), and Figure 1d shows the same as Figure 1c, but with temporal filtering window 5, showing further noise reduction.

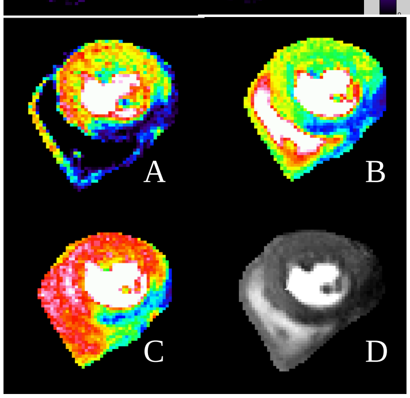


Figure 2 shows a comparison between parametric maps using temporal filtering and average foot and peak values (a) slope, (b) area $t_{foot\text{-}avg}$ to $t_{peak\text{-}avg}$, (c) SI at $t_{peak\text{-}avg}$ and (d) grayscale image of the summation from foot to peak for reference.

**Discussion**

Although the method described does not allow comparison between studies in terms of absolute values of slope, area under curve, peak intensity, it does provide a compact method of visualizing the temporal dynamics of first pass myocardial perfusion imaging, with relatively high SNR, preservation of underlying spatial resolution and minimal user interaction. Applications could include increasing confidence in interpretation due to elimination of transient artifacts and development of tissue classification methods to separate ischemic, infarcted and normally perfused tissue. With use of model based methods for determination or constraint of the foot or peak values, one could further improve the quantification and allow more detailed analysis. The authors wish to thank Dr CH Luk, Hong Kong and Dr Yiu-Cho Chung, Siemens for the use of the images.

| **Table 1** | No temporal filtering, avg peak, foot | 5 point temporal filter, avg peak, foot |
|---|---|---|
| slope | CNR 1.59 +/- 0.59, SNR 35.18 +/- 32.31 | CNR 2.99 +/- 0.91 SNR 79.22 +/- 86.94 |
| Area | CNR 3.50 +/- 1.20 SNR 2.71 +/- 1.76 | CNR 3.17 +/- 1.27 SNR 2.91 +/- 1.70 |
| SI at Avg Peak | CNR 2.38 +/- 0.90 SNR 9.03 +/- 5.15 | CNR 3.61 +/- 1.08 SNR 14.48 +/- 8.94 |

**References**

[1] Panting JR et al. JMRI. 2001;13(2):192.
[2] Y. Sun et al, *Proc. Medical Image Computing and Computer-Assisted Intervention*, 2004