Parametric Mapping of Contrast Kinetics from Rapid Radial DCE-MR Breast Images

L. Dougherty[1], H. K. Song[1], P. J. Moate[2], L. W. Nunes[3], M. A. Rosen[1], R. C. Boston[2]

[1]Radiology, University of Pennsylvania, Philadelphia, PA, United States, [2]School of Veterinary Medicine, University of Pennsylvania, Philadelphia, PA, United States, [3]Radiology, Pennsylvania Hospital, Philadelphia, PA, United States

Introduction:

In the last decade there has been increasing use of contrast reagents (CR) for the dynamic imaging of tumors. Researchers have developed a variety of techniques to analyze such data with the aim to use the information imbedded in these curves to improve the differential diagnosis of malignant and benign tumors. In comparison to the compartmental model approach, heuristic models make no assumptions or inferences about the underlying physiology of a tumor, but simply attempt to describe the important features or attributes of the uptake of CR by the tumor. Such heuristic parameters include: (1) baseline signal enhancement, (2) rate of enhancement, (3) time to peak enhancement, (4) peak enhancement, and (5) terminal slope. Heuristic models focus on parameters 2-5 since these have been implicated in aiding the diagnosis of malignant tumors.

A method for the simultaneous acquisition of both high spatial and temporal resolution DCE-MR breast images was previously described [1,2] that used an interleaved radial acquisition in conjunction with a multi-resolution reconstruction to achieve a temporal resolution of 15 seconds per frame for a 512 x 512 x 32-slice acquisition over both breast simultaneously. This report describes the analysis of the contrast kinetics from these images using a modified heuristic model and the presentation of significant curve characteristics as parametric color maps.

Methods:

IRB approval was obtained prior to the start of this study. Women with suspicious mammographic or palpable breast abnormalities were included in this study**.** After informed consent, patients were placed in the scanner (1.5T Siemens Sonata, Siemens Medical Systems, Iselin, NJ) in the prone position, with the breasts gently compressed within a receive-only breast coil. A high-resolution baseline volume was acquired followed by dynamic imaging started simultaneously with the intravenous injection of 0.1-mmol/kg gadopentetate dimeglumine (Magnevist, Berlex Laboratories, Wayne, NJ). Contrast was administered over a 10-second interval and followed by a saline flush. Post-contrast data were acquired over the following 6-minute period. The contrast-enhanced images were acquired using a fast 3D spoiled gradient-recalled back-projection sequence using 512 data samples/projection with 384 projections, and 32 phase encoding steps in the slice direction. Other imaging parameters were: repetition time (TR) = 9.8 ms; echo time (TE) = 4 ms; flip angle=20°; and the sampling bandwidth was 260 Hz/pixel. The images were acquired using a 24 cm FOV and ~3 mm thick slices in the sagittal plane.

A custom computer program was written to allow the user to view the breast images and analyze the contrast kinetics. From the reconstructed images the signal intensity data were obtained and fit to a five parameter modified logistic equation given by [3]:

$$SI(t) = \frac{P_2 + (P_5 \bullet t)}{\{1 + \exp(-P_4 \bullet (t - P_3))\}} +$$

In this heuristic model, $P_1$is the baseline signal, P_2 is related to the magnitude of the peak signal enhancement, P_3 is the time of the maximum rate of increase of signal, P_4 is the maximum rate of signal enhancement and P_5 is the terminal slope of the signal enhancement curve. The time signal enhancement curve could be shown for any user selectable ROI or the curve parameters could be generated for each pixel and shown as a color overlay on the breast images.

Results:

A logistic model to predict pathology was developed based on the kinetic parameters obtained from 68 breast lesions. Color maps were defined that indicated a high probability of being benign (green), malignant (red) or if there was poor confidence in the correlation, the pixels were classified as unknown (blue). In 9 subsequent studies, using the P_2 and P_5 parameters alone, 4 malignant and 5 benign lesions were correctly classified. Figure 1 shows a representative case showing a malignant lesion and the P_2, P_3, and P_5 parametric maps.

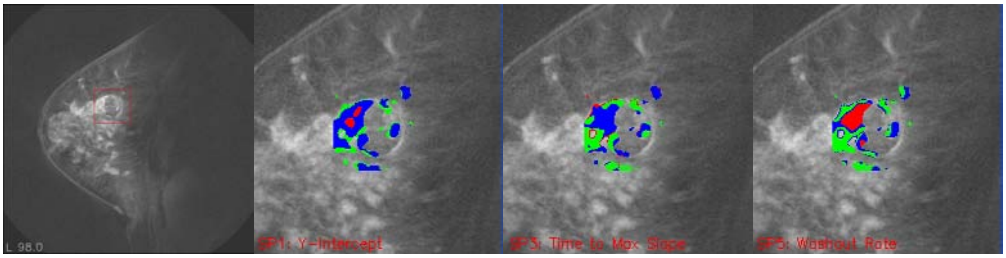

Figure 1. DCE-MR breast image with color maps of the heuristic model parameters. (P_2, P_3, P_5 *)*

Conclusions

Classification of curve parameters from a heuristic model of lesion enhancement using high-temporal resolution DCE-MRI is a useful means of characterizing benign and malignant breast lesions.

References

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