Dynamic Contrast-enhanced MRI for Detection of Bone Metastases from Prostate Carcinoma: a Study of Kinetic Parameter with Reference Local Voxel Cluster Model

Huairui Du1, Wenchao Cai1, Jue Zhang1, Xiaoying Wang2, and Jing Fang1,3

1College of Engineering, Peking University, Beijing, China, 2Peking University First Hospital, Beijing, China, 3Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, Beijing, China

Purpose:
To evaluate bone metastases (BM) from prostate cancer by using kinetic parameters of dynamic contrast enhanced MR imaging from the proposed reference local voxel cluster (RLVC) model.

Materials and Methods:
Fourteen patients, pathologically proved of prostate cancer, were recruited in this study. Totally, 41 bone metastatic lesions were determined by imaging and clinical evaluation. All patients underwent MR examination, including T1 weighted imaging, T2 weighted imaging, diffusion weighted imaging (DWI), and dynamic contrast-enhanced (DCE) imaging. DCE-MRI quantitative parameters (including rate constant for passive contrast reagent transfer between plasma and interstitium (Ktrans) and interstitial space volume fraction (vI)) of the metastatic lesion, normal bone, and pelvic muscle were extracted by RLVC, expressed as formula (1).

\[
\alpha \sum_{j} \left( \frac{1}{K_{\text{trans}}} - \frac{1}{K_{\text{max}}} \right)^2 + \frac{1}{v_i} + \left( \frac{1}{v_i} \right)^2 + \frac{1}{K_{\text{trans}}} - \frac{1}{K_{\text{max}}} \right)^2 + \frac{1}{v_i} \right)^2 \right)
\]

The kinetic parameters of metastatic bones and normal bones were compared, with independent T-test. Paired T-test was used to compare the metastatic area between the Ktrans Map and DWI.

Results:
All lesions are detected by RLVC based Ktrans Map (100%) while a total of 38 lesions are detected by DWI(92.6%) from the 41 bone metastatic lesions. It was demonstrated in Fig. 1 that the kinetic parameters of BM are significantly higher than those of normal bones (metastatic foci Ktrans 0.101±0.029 min-1 and vI 0.595±0.117; normal bones Ktrans 0.017±0.009 min-1 and vI 0.411±0.065). The average area (Fig. 2,3) of the 41 metastatic lesions (929.93 mm²) in the Ktrans Map is significantly larger than that (425.32 mm²) of DWI (P<0.001).

Conclusions:
Results suggest that the kinetic parameters (Ktrans, vI) extracted from the proposed RLVC model are effective, and compared to the corresponding DWI image, Ktrans map exhibit larger abnormal area, indicating its higher sensitivity for metastases. It is closely associated with the processes of cancer metastasis that tumors must induce the formation of neovascularity if they are to grow beyond minimal size [1]. While DWI mainly depicts water mobility determined by the interaction of water with intracellular elements, macromolecules, cell membranes, cell density, and microstructural organization [2], Ktrans can reveal the tissue permeability and perfusion property caused by arterial blood vessels proliferation, and determined by the abundance and transfer rate of vessels in region of interest. Disease processes that alter the characteristics of cells, including cell-water homeostasis, cell density, and cytoarchitecture affect water mobility, and by the conventional T1WI, T2WI and DWI (high b value), the change of those characteristics can only be found out when the tumor foci contains enough cancerous cells. In contrast, hypervascularity, which can be detected by the Ktrans plays a major role, such as supplying essentials in the early stage of bone tumor infiltration from prostate carcinoma. Thus it is believed that the RLVC model could provide a valuable tool for the potential detection of early bone metastasis.

References: