The Perfusion Bias in Lumbar Vertibra by One Slice of DCE-MRI Measurement

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Introduction: Because the characteristics of bone vascularity in spine marrow [1], DEC-MRI can be widely applied in exploring spine diseases. Vertebral blood perfusion has been reported to be decreased in normal aging people [2], those with osteoporosis and increased fatty marrow [3]. Recently, radiologists observed with DCE-MRI and reported that the high correlation between degeneration of disc and low vertebra perfusion [4]. Most of the previous studies reported measurement of the vertebral marrow perfusion at the center of vertebral column on sagittal plane [2], and few of them used axial [5] and coronal plane [6]. According to the anatomy of vertebral body, the best imaging plane for evaluating blood perfusion is the axial image of the vertebral body because of the disc shaped and course of a pair (left and right) segmental artery. To accurate sampling the process of blood wash-in and wash-out, a fast T1WI MR sequence with single thick slice was performed for DCE-MRI measurement and one large ROI covered whole vertebral body in the thick slice was used to evaluate the entirety vertebra in most studies of spine perfusion. Because of the inhomogeneous perfusion in vertebral body and only enrolled partial volume of vertebral body usin one slice image, it is reasonable to make an assumption that the bias should be present in DCE-MRI examination. In this study, to demonstrate the hypothesis that blood perfusion is regional dependent in vertebral body and evaluate the variation in different anatomical plane, the sagittal and coronal plane were simulated by the axial plane data and blood perfusion was compared among those three planes.

Method: This study enrolled 25 subjects (70 normal vertebral bodies). DCE-MRI was employed to measure the perfusion of the lumbar vertebral body using axial section at the center of the each vertebra. Three continuous axial images of the vertebrae (L1, L2, and L3) were selected for measurement. Fast RF-spoiled gradient-recalled (FSPGR) sequence (TR/TE = 10/1.4 ms; flip angle = 30°; FOV = 30×15 cm; matrix size = 256×160; slice thickness = 10 mm) was applied in each experiment. The interval time between each measurement will be 3.1 seconds and total acquired time will be 8 minutes. Bolus Gd-DTPA injection with a total dose of 0.1 mmole/kg via auto-injector at a rate of 2 ml/sec was followed by a 10 ml saline flush at the same rate. The data of DCE-MRI images was analyzed with a region of interest (ROI) on axial planes by operator-defined over the whole vertebral body (Fig.1A). Three vertical bands were divided equally in ROI, and the middle column band was used to simulate the ROI on sagittal plane (Fig.1B). Similarly, the middle row band simulated the ROI on coronal plane (Fig.1C). The mean signal-time-curves in axial ROI, sagittal ROI and coronal ROI were used to fit the Brix model equation by nonlinear least square error curve fitting. In this study, the peak enhancement values of fitted signal-time curves, the slope of wash-in and wash-out (Fig.1D) were computed in three ROIs (axial ROI, sagittal ROI and coronal ROI) for evaluating the regional inconsistency. The ratio of minimum to maximum perfusion parameters (peak and slope) among axial, sagittal and coronal ROI was as an index to evaluate the perfusion variation by anatomical plane measurement.

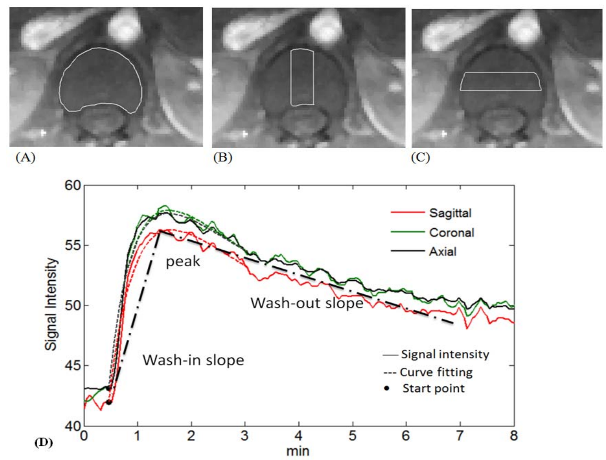

Fig 1. (A) Axial DCE-MRI image shows the operator-defined regions of interest (ROIs) over the entire axial vertebral body ROI, (B) sagittal ROI and (C) coronal ROI to measure the signal time values. (D) The signal was averaged by all pixels measured from the ROI.

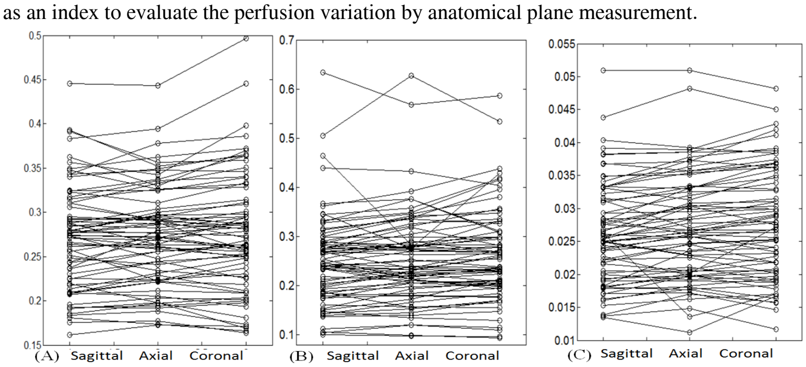

Fig 2. It plots the peak enhancement against sagittal, axial and coronal ROI, Figure 2B and 2C plot the slope of wash-in and wash-out respectively. It is obviously observed that the parameters of perfusion are no regular order for axial, sagittal and coronal ROI.

Results: Fig. 2A plots the peak enhancement against axial, sagittal and coronal ROI, Fig. 2B and 2C plot the slope of wash-in and wash-out respectively. Fig. 3 shows the ratio of minimum to maximum parameters (peak and slope) among axial, sagittal and coronal ROI. The ratio of minimum to maximum is 0.922±0.038 (mean±SD) in peak enhancement, and the ratios of minimum to maximum are 0.875±0.075 and 0.886±0.08 in slope of wash-in and wash-out respectively. The probability, the number of smaller than 0.9 in the ratio of minimum to maximum, are 23%, 59% and 50% for peak enhancement, slope of wash-in and wash-out respectively.

Discussion: Our study has demonstrated the blood perfusion in healthy vertebra is variation using the three different anatomical planes ROIs. The normal vertebral body is composed of mineralized substances, the cortical and trabecular network, vascular network, and medullary mesenchyma. Moreover the significant negative correlation found between peak enhancement and fat content [5]. Obviously the distribution of blood vessels and capillaries is regional inhomogeneous in healthy vertebra body due to overall factors mentioned above. Our results show three perfusion parameters (peak, wash-in and wash-out slope) are different and irregular order among three ROIs (Fig.2), and also present the ratios of minimum to maximum among three locations are variable (Fig.3). It represents the errors of perfusion measurement by alterant location inside vertebra only are 8% in peak enhancement, 13% and 11% in slope of wash-in and wash-out respectively. The probabilities of over 10% error are 23%, 59% and 50% for peak enhancement, slope of wash-in and wash-out respectively (Fig.3).

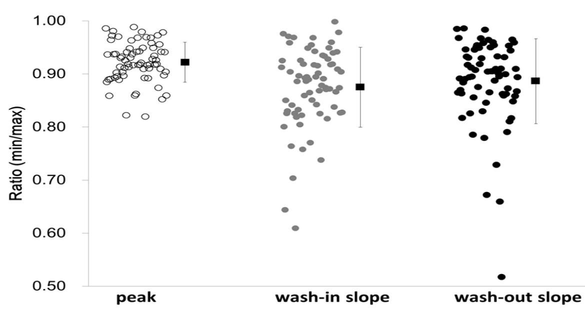

Fig 3. The scatter diagram of ratios of minimum to maximum among three ROIs is illustrated in peak enhancement, wash-in slope and wash-out slope respectively. The average and standard deviation is also showed in peak enhancement (0.922±0.038), slope of wash-in (0.875±0.075) and wash-out (0.886±0.08) respectively.

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