Analyses of restricted diffusion of water molecules using trabecular bone phantom

R. Yorimitsu[1], T. Miyati[1], T. Minami[1], H. Kasai[2], N. Arai[2], H. Kan[1], A. Kitanaka[1], T. Matsushita[1], M. Hara[2], and Y. Shibamoto[2]

[1]Division of Health Sciences, Graduate School of Medical Science, Kanazawa University, Kanazawa, Ishikawa, Japan, [2]Department of Radiology, Nagoya City University Hospital

INTRODUCTION:

Yeung et al described that fat degeneration of bone marrow related to osteoporosis, i.e., low BMD, was reflected by a decreasing apparent diffusion coefficient (ADC) [1]. In addition we earlier reported that the ADC was correlated with the BMD and fat fraction [2], but the relation between the restricted diffusion of the water molecules and the trabecular bone structure was unclear. On the other hand, numerous studies indicated that the diffusion-weighted signal from a single voxel could be described as the sum of two exponential functions, i.e., fast and slow diffusing components [3]. The purpose of our study was to clarify the relationship between those diffusing components and trabecular bone structure with an original phantom.

METHODS:

On a 1.5-T MRI, single-shot diffusion EPI was used with b values of 0 to 3000 s/mm^2, and a sensitivity encoding technique. We obtained the signal decay with b from selected regions of interest within a trabecular bone phantom, which consisted of seven sponges changing the interspace areas, and dry vertebral bone in a container filled with pure water (Fig.1). Then these signals were fitted by using biexponential function after noise correction.

RESULTS AND DISCUSSION:

A significant positive correlation was found between mean effective interspace diameter of the simulated trabecular bone and the fraction or ADC of the fast component (Fig. 2a and b). On the other hand, a significant negative correlation was found between the interspace diameter of the simulated trabecular bone and fraction of the slow component (Fig. 2c), and a strong positive correlation was found between the interspace diameter and the ADC of the slow component (Fig. 2d). These results show that restricted diffusion of the water molecules depends on the interspace diameter of the simulated trabecular bone and fraction of each component. Moreover, the fraction and the ADC of the dry vertebral bone agreed with those of the simulated trabecular bone (Fig. 2). This result means that our phantoms can reproduce actual trabecular bone structure, which induces the restricted diffusion.

CONCLUSION:

Our original phantom enables to assess restricted diffusion, and the analytical method could obtain more detailed information on trabecular bone structure.

REFARENCES:

[1] Yeung DK, et al, J Magn Reson Imag, 19; 222-228, 2004.
[2] Ueda Y, et al, J Magn Reson Imag, 31; 632-635, 2010.
[3] Nienodorf T, et al, Magn Reson Med, 36; 847-857, 2001.

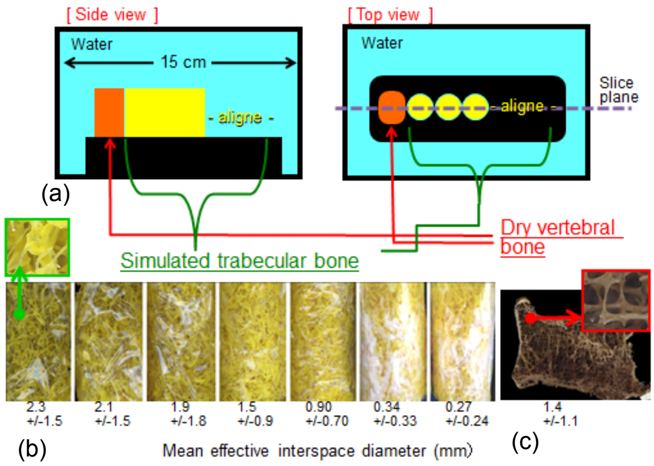

Fig. 1 Trabecular bone phantom. (a) Phantom container, (b) simulated trabecular bone, and (c) dry vertebral bone.

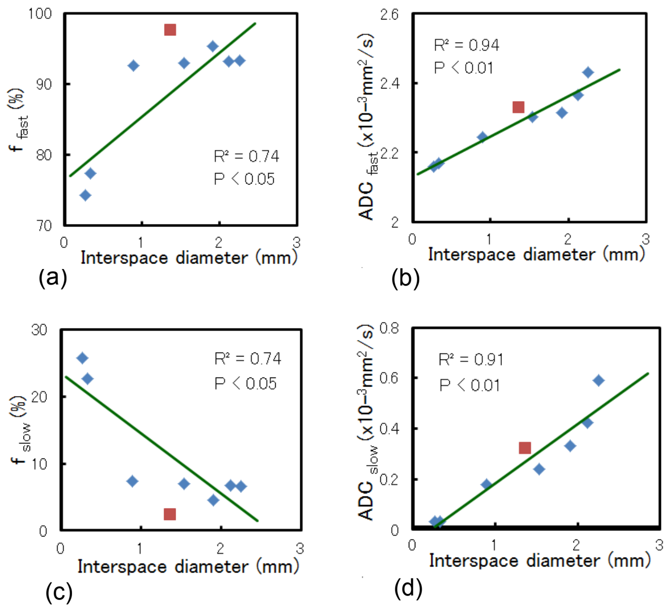

Fig. 2 Relation among each diffusion component, interspace diameter of the simulated trabecular bone (◆) and dry vertebral bone (■). (a) Fraction of the fast diffusing component, (b) ADC of fast diffusing component, (c) fraction of the slow diffusing component, and (d) ADC of the slow diffusing component.