Accurate Bone Marrow Extraction from T1-w Images and ADC-maps in Patients with Metastatic Cancer: A Texture-Based Segmentation Approach

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Target Audience: Oncologists, Radiologists, Physicists and Engineers Interested in Treatment of Bone Metastases

Introduction: In bone marrow metastatic cancers, accurate diagnosis of the bone state in the shortest possible time is the key to achieve therapy goals, which aims to relieve the symptoms and improves the patient's quality of life. In this light, diffusion weighted imaging (DWI) has shown great promise in providing valuable information about tissue microstructure characteristics[1-4]. The calculated apparent diffusion coefficient (ADC) reflects cellular density, the tortuosity of the extracellular space, cell membrane integrity, fluid homeostasis and microcapillary perfusion[5]. The changes in water diffusivity in bone marrow through ADC-values over the course of treatment would allow for indicating the response to treatment. For extracting statistical properties of ADC-map histograms, the bone marrow should be segregated in advance. Although this segregation is of relevance in clinical study, manual region-of-interest (ROI)s selection on the ADC-maps is preferred by experts which maybe limited due to its irreproducibility, time-consuming procedure, mis-registration, the heterogeneous nature of the tumor and also the presence of cystic or necrotic areas before therapy. Here, a fully automatic scheme for segmentation of bone marrow metastatic breast cancer from T_1-weighted (T_1-w) images in the pelvis organ is presented. In contrary to the previously proposed work[5], our automatic approach requires no prior information while maintaining higher accuracy in bone marrow extraction.

Materials and Methods: *Data* Acquisition: Whole-body T1-w and diffusion-weighted images of 10 breast cancer patients with bone marrow metastases under treatment, were acquired on a 1.5T MR scanner (Siemens, MAGNETOM Avanto). T1-weighted images were acquired with the following specifications: TR/TE = 171/4.76 ms, matrix size = 256×151, field of view (FOV) = 430×430 mm^2, slice thickness = 5mm, spaces between slices = 5.5 mm. DWI was performed using a GE-EPI sequence with TR/TE= 5540/102 ms, matrix size = 256×151, FOV = 430×430 mm^2, slice thickness = 5mm, spaces between slices = 0.5 mm, at b-values of 50, and 900 sec/mm^2. ADC maps were then calculated from DW images. Image *Processing and Analysis:* Image processing and analysis consists of the following steps: 1) SPM8 software[6] is employed for non-rigid registration of the whole-body T_1–w MR images with the ADC-maps, for motion correction and image resizing, by employing normalized mutual information (NMI) as the registration objective function and Trilinear interpolation method as the deformation model; 2) in order to extract bone marrows, a texture-based segmentation method is applied on each slice of T1-w images; 3) creating and overlaying the bone marrow mask, created from T1-w segmented images, on the corresponding ADC-maps for bone marrow.

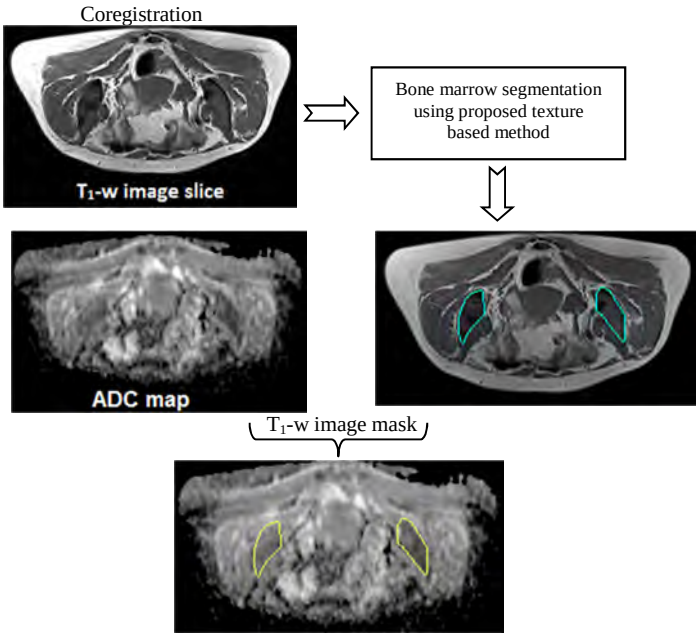
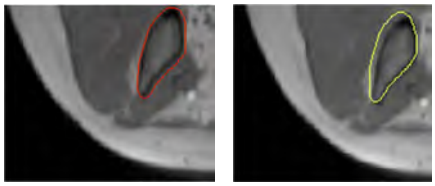


Figure 1. The proposed algorithm

Results and Conclusions: The overall steps of bone marrow segmentation from a sample slice of T_1-w images and its corresponding slice from the ADC-map is indicated in **Fig. 1.** As illustrated, the segementation procedure is performed without any predifined manual ROIs. For performance evaluation of the proposed segmentation method as well as its superiority over a previously proposed method by Sanaei Nezhad *et al*[5], both techniques were applied to the same datasets and the results were compared to manually extracted bone marrows, selected by a expert radiologist. A comparison between the methods is illustrated in **Fig. 2.** Also, **Table 1** represents a quantitative analogy between the methods using Dice score. It is apparent that our method outperforms the other technique by about 10%, and therefore could more accurately extract bone marrows from T1-w images and ADC maps. Moreover, unlike the Sanaei Nezhad et al.'s method, in our implementation no prior information is employed. Since more texture could be observed in ADC maps from image processing point of view, it seems that our proposed texture-based segmentation procedure could be applied directly on ADC-maps independent of the T1-w images. To conclude, the texture-based segmentation approach presented in this work could accurately and reliably be applied for automatic segmentation of T1-w images and ADC-maps, which could facilitate quantitative assessment of whole-body bone marrow metastasis.



a b

Figure 2. The comparison between the methods. a) Our proposed method Versus b) Sanaei Nezhad's method

Method / Measurement	Our Proposed Method	Sanaei Nezhad's Method
Dice	0.91 ± 0.03	0.83 ±0.06

Table 1. The mean and standard deviation of Dice measurement for Our proposed method and Sanaei Nezhad method[6] for bone marrow extraction.

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