Assessing the advantages of whole body Diffusion Tensor Imaging for screening of bone metastases

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Introduction: A critical requirement for evaluating cancer patient prognosis and treatment planning is knowledge of the location and total burden of metastatic spread. Although bone is the third most common site of metastases, current methods of detecting disease location and assessing aggressiveness are subject to limitations. The commonly used method of skeletal scintigraphy (SS) suffers from many disadvantages including low resolution and poor sensitivity [1], and an alternative technique is needed. A recent technological development by Takahara *et al.*, namely whole body Diffusion Weighted Imaging with Background signal Suppression (DWIBS) [2], utilises high b-value diffusion weighted imaging to suppress signal from spins moving freely within tissue, leaving high signal from long T2 tissues where motion is hindered (e.g. tumours and certain normal anatomical structures). Previous reports have demonstrated DWIBS to have equivocal or superior sensitivity when compared to SS and PET/CT although specificity is compromised due to the presence of benign tissues that can mimic disease [3]. Another successful development of DWI that has been applied extensively in brain [4] is diffusion tensor imaging (DTI) where b-values are applied in multiple directions such that the orientational dependence of water diffusion in tissues can be measured. Whilst there have been reports on the use of DTI in the spinal cord [5], there have been no attempts, to our knowledge, to use DTI in the context of whole body imaging of cancer. As DTI measurements provide a diffusion tensor at each pixel location, other biological parameters such as fractional anisotropy (FA) may be obtained which could be important markers for identifying abnormalities. The purpose of this study was to address whether such a measurement employing a 6 direction DTI protocol would be feasible based on volunteer results from a Siemens 'Avanto' 1.5T scanner.

Method: DWIBS images were obtained using both a standard trace weighted protocol with 3 orthogonal directions and also using a 6-direction DTI measurement for direct comparison. Whilst the number of signal averages (NSA) for the standard DWIBS acquisition was 4, the NSA for the DTI scheme was halved (NSA = 2) to ensure the same total acquisition time. Diffusion weighting was applied using a b-value of 900 s mm^{-2} in both cases and b = 0 s mm^{-2} images were also acquired to allow for ADC calculation. Other imaging parameters that remained the same for both acquisition strategies were: resolution = 2.5x2.5x5 mm^3, field-of-view = 38x38x25 cm^3, TE = 74 ms, TR = 14100 ms, STIR fat suppression with an inversion time of 180 ms and GRAPPA parallel imaging with an acceleration factor of 2. All images were acquired using a double spin echo technique to reduce eddy current distortions [6] over 3 separate stations with 50 slices per station. Trace weighted images were derived from the DTI data as the sum of diagonals of the diffusion tensors and whole body MIPs of these maps were generated and compared side-by-side with the MIPs from the standard trace method. Whole body fractional anisotropy maps were also generated using the DTI results.

Results: Shown in figures 1(a-b) are whole body MIPs from the b-900 trace images of the standard DWIBS method and the new DTI-DWIBS technique respectively. Note that there is little difference in the quality of both images. Figure 1(c) shows an example FA map generated from a curved reformatted multi-planar reconstruction image along the spinal cord and 1(d) displays a sagittal view of a colour coded directional map, derived from the diffusion tensors.

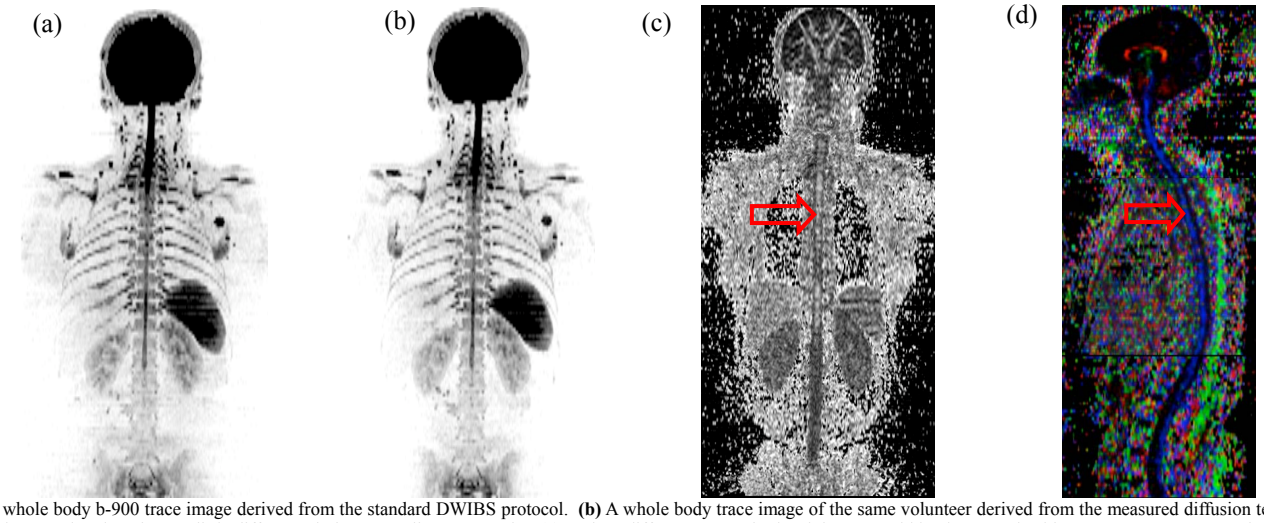

Figure 1 (a) A whole body b-900 trace image derived from the standard DWIBS protocol. **(b)** A whole body trace image of the same volunteer derived from the measured diffusion tensors of the DTI DWIBS protocol. Note that there is very little difference in image quality compared to (a). Minor differences seen in the abdomen could be due to peristaltic movement. **(c)** A curved reformatted multi-planar reconstruction of the FA map along the spinal column calculated from the DTI data. Dark regions indicate low fractional anisotropy associated with isotropic diffusion. Brighter areas indicate that diffusion is more biased along a single direction as clearly shown in the spinal cord (red arrow). **(d)** A sagittal colour coded FA map where colours represent the principle axis of diffusion: blue = head-foot, red = left-right, green = ant-pos. Note the clarity of prevalence of diffusion in the spinal cord to be along the head-foot direction as indicated by the blue colour (red arrow). We believe that the green voxels shown at the posterior of the volunteer to be artefactual and will be investigated further in the future.

Conclusions: We have demonstrated that the use of whole body DTI is feasible and practicable in the time required to obtain standard diffusion weighted whole body measurements of bone metastases without significant loss in image quality (if any). Furthermore, by utilising the diffusion tensors obtained from whole body DTI it is possible to measure useful biological parameters such as fractional anisotropy as demonstrated in figures 1(c-d). Whilst the FA is heavily affected by noise in many organs, the spinal cord is clearly identified and the principle axis of diffusion may be observed. We believe that this may have direct clinical relevance in detecting spinal cord compression, a symptom that we have seen in numerous patients with bone metastases, where we predict a large change in the FA index would be observed. Furthermore, we have more confidence in estimates of trace ADC value as we apply diffusion weighting in more directions than with the standard DWIBS approach.

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