COMPARISON BETWEEN WHOLE-BODY CORONAL AND AXIAL DWI PERFORMED DURING PET-MR

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Target audience: Clinicians with an interest in oncology, PET-MR and whole-body DWI.

Purpose: Whole-Body (WB) Diffusion Weighted Imaging (DWI) is increasingly being used to detect distant metastasis in cancer patients[1]. A commonly used technique for WB DWI is DWIBS (Diffusion-weighted Whole-body Imaging with Background Suppression), which consists of a series of axial free-breathing acquisitions with STIR (Short-Tau Inversion Recovery), specifically designed to minimize sensitivity to B0 inhomogeneity. Direct coronal DWI with acceleration factors up to 5 has been recently proposed to overcome the main limitations of DWIBS (i.e. long acquisition times, stair-steps artifacts in the coronal reformats and intrinsically low SNR), but this technique has been demonstrated only in conjunction with specific coil technologies and could suffer from excessive noise amplification with conventional array coils. The use of 2D RF pulses combined with low acceleration factors has been shown to provide coronal DWI images with low distortion and excellent fat suppression, with acquisition times similar to those achievable with direct coronal DWI[2] (~2mins per station). Unlike DWIBS and direct coronal DWI, this technique exploits the low excitation bandwidth of the 2D RF pulse in the slice direction to suppress fat, resulting in higher SNR but increased sensitivity to B0 variations. In addition, while feasibility of coronal DWI for WB imaging has been demonstrated, it is unclear whether there is a diagnostic advantage in terms of ease of interpretation in direct coronal acquisitions. The purpose of this study was to compare coronally and axially acquired DWI images obtained using a previously reported 2D selective DWI method with low acceleration factors[2] in terms of image quality and ability to identify potentially malignant lesions with respect to PET-CT as the gold standard.

Methods: *Protocol:* Fourteen patients with a history of malignancy underwent same day PET-CT followed by PET-MR exams (Signa PET-MR, GE Healthcare, Waukesha, WI). PET/CT was performed in 3D mode on GE Discovery 600/690 PET/CT using a standard clinical protocol after injection of a dose of 10 mCi of 18F FDG. The MR portion of the exam included DWI acquired in coronal (cDWI) and axial (aDWI) planes. cDWI was performed using a custom-developed 2D Single-Shot Diffusion Weighted Echo Planar Imaging pulse sequence, with 2D spatial selectivity obtained by replacing the conventional spectral-spatial excitation pulse with a 2D RF pulse[2] The combined effect of the 2D excitation and 180 refocusing pulse ensured fat suppression without the need for additional pulses. For coronal acquisitions, S/I phase encoding was performed to minimize the echo train length (hence distortion) while using low acceleration factors to avoid excessive noise amplification. A parallel imaging factor of 2 was sufficient to obtain 25cm S/I coverage per station. For the comparative purpose of this study, the same exact acquisition was used axially, although the 2D selectivity provided by the 2D RF was not exploited when imaging in this plane. Imaging parameters were: TE=62(cor)/67(ax)ms, TR=2.5s, , slice thickness = 8mm, 32 consecutive sections, phase FOV = 0.55(cor)/0.7(ax), matrix size = 160x160(cor)/128x160(ax), b = 50 [8 NEX] and 800 [16 NEX] s/mm^2. Half Fourier with homodyne reconstruction and a Stejskal-Tanner diffusion encoding scheme with gradients played out on all 3 axis simultaneously were used for both cDWI and aDWI. Each acquisition took about 2min. per station.

Image evaluation: Two radiologists rated images from stations 1 to 6 (covering anatomy from head vertex to lower thigh) on a 4 point scale for the following categories: a) overall image quality b) quality of fat saturation c) distortion (1=poor, 2=fair, 3=good, 4=excellent). Images were evaluated prior to stitching in the original acquired plane without grayscale inversion. In addition, readers assigned a score to each organ (19 organs per patient) based on their confidence regarding the presence or absence of malignancy (1=definitely benign, 2=probably benign, 3=equivocal, 4=probably malignant, 5=definitely malignant). Findings on MR were compared to PET-CT clinical report findings as the gold standard. A confidence score of 1 or 2 was considered absence of disease; scores of 4 or 5 were considered presence of disease; a score of 3 was treated as absence of disease if no lesions were identified and as presence of disease if equivocal lesions were found. The number of suspicious foci in each organ was noted (up to a maximum of 5 per organ). The conspicuity and delineation of suspicious lesions, if any, were scored using the 4-point scale described above. The Wilcoxon sign-rank test was used to assess if differences in overall image quality, fat suppression, distortion, lesion conspicuity and delineation between cDWI and aDWI were statistically significant, with $p \leq 0.05$ considered statistically significant.

Results: On a per-organ basis, both readers similarly demonstrated good sensitivity and excellent specificity on cDWI and aDWI (Table 1). On a per-patient basis, specificity was lower on cDWI compared to aDWI for both readers, which may have been partially due to the small sample size. Both readers demonstrated less uncertainty regarding findings (confidence score of 3) on cDWI compared to aDWI (reader 1: 6.7% vs 10.5% of organs rated, respectively; reader 2: 2.2% vs 6.0%). False negatives on cDWI and aDWI involved disease in the pelvic organs (2) and lungs (1). False positives on cDWI involved findings in the spine (4), pelvic bones and femurs (4), as well as abdominal/pelvic lymph nodes (4). On aDWI, false positives most commonly involved the pelvis and femurs (4) and abdominal/pelvic lymph nodes (2); however, the spine was not the source of any false positive findings on aDWI.

		Reader 1		Reader 2	
		Coronal	Axial	Coronal	Axial
Sensitivity	Per-patient	85.7%	85.7%	71.4%	71.4%
	Per-organ	88.0%	88.0%	84.0%	84.0%
Specificity	Per-patient	57.1%	71.4%	71.4%	85.7%
	Per-organ	95.4%	97.9%	96.3%	97.5%

Table 1. cDWI vs. aDWI performance compared to PET-CT.

Overall image quality was rated significantly higher on cDWI by both readers (reader 1: p=0.001; reader 2: p=0.04). Distortion was also rated more favorably on cDWI, however, the difference was only significant for reader 1 (p=0.008). Images in stations 2 and 3 (covering region of neck and shoulders and upper chest, respectively) were rated as having the lowest overall image quality on both cDWI and aDWI (station 2: 2.6 vs 2.3; station 3: 2.8 vs 2.8), due to the large susceptibility variations present in these regions and known difficulty to accurately shim these areas. Lesion conspicuity and delineation were not significantly different on cDWI and aDWI for both readers (reader 1: 3.8 vs 3.7, 3.6 vs 3.5; reader 2: 3.0 vs 3.1, 3.2 vs 3.2) (Figure 2).

Conclusion: Both cDWI and aDWI performed well compared to PET-CT on a per-organ basis; however, specificity on a per-patient basis was fair, largely due to false positive findings in osseous structures and lymph nodes. Uncertainty regarding presence of disease was lower on cDWI images, which may be partially due to overall higher image quality and lower distortion. High sensitivity to off-resonance due to the low slice-select bandwidth of the 2D RF resulted in degraded image quality when imaging in proximity to tissue-air interfaces and other sources of off-resonance. A conventional excitation in conjunction with inner volume/outer volume suppression techniques to preserve the 2D selectivity and STIR fat suppression could be used to mitigate B0 sensitivity for those stations where off-resonance is known to be worst.

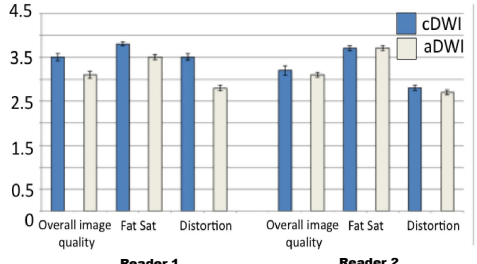

Figure 1. cDWI and aDWI image evaluation.

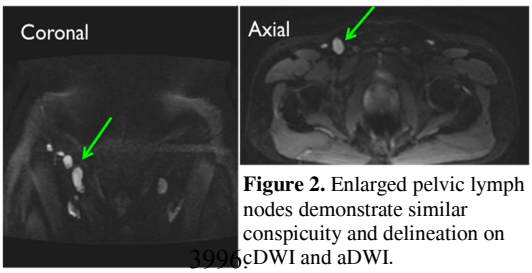

Figure 2. Enlarged pelvic lymph nodes demonstrate similar conspicuity and delineation on cDWI and aDWI.

References: [1] Del Vescovo R. et al, Radiol Med 2014, p. 758. [2] Fung M.M. et al, ISMRM 2014, p.2238.

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Disclaimer: Data acquired using an investigational device that is 510k pending at FDA. Not approved for sale. Not for sale in all regions.