Evaluation of PET/DWI registration quality in PET/MR hybrid scanner: zoomed DWI vs. conventional DWI

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Target audience: Researchers and clinicians interested in PET/MR hybrid imaging.

Purpose: PET/MR hybrid system provides simultaneous molecular information from PET and diffusion-weighted EPI image (DWI). However, severe image distortion is often observed in conventional DWI (c-DWI) and registration quality of PET/DWI is degraded. Zoomed DWI (z-DWI) can reduce field of view (FOV) along the phase-encoding direction by exploiting spatially-selective RF pulse and is expected to reduce susceptibility artifact and image distortion by shortening the EPI echo train[1, 2]. The aim of this study is to optimize imaging parameters for z-DWI in phantom study and to compare z-DWI with c-DWI in the evaluation of PET/DWI registration quality in patient study.

Materials and Methods: *Phantom Study:* Three sample tubes filled with saline, air and vegetable oil were inserted in a PVA-filled MR phantom (Nikko Fines Industries, Tokyo, Japan). MR imaging was performed with the Ingenuity TF PET/MR system (Philips, Cleveland, US) using a 32-channel head coil. After acquisition of high-resolution T2WI as a reference, c-DWI with single-shot EPI sequence (FOV = 300^2 mm, acquisition matrix = 152^2, reconstruction matrix = 224^2, thickness = 5 mm, SENSE factor = 2.5) was used to image the whole phantom. Other imaging parameters for c-DWI were: b factor = 800, TR/TE = 2250/62, NEX = 2, scan time = 15 sec, receiver bandwidth = 21.4 Hz. Following c-DWI, z-DWI were also acquired with rectangular field of view (RFOV) set at 100%, 80%, 60% and 40% by reducing the number of phase-encodes. The length along frequency-encoding direction was fixed at 225 mm. Spatial resolution and SENSE factor used in z-DWI were equal to those used in c-DWI. Other imaging parameters for z-DWI were: b factor = 800, TR/TE = 1970/62, NEX = 2, scan time = 27 sec, receiver bandwidth = maximum. Imaging analysis was performed on a commercially available workstation (Intellispace Portal 6.0, Philips, Cleveland, US). On T2WI, circular regions-of-interests (ROIs) were placed on each sample tube in way to cover just 100% of the tubes. On c-DWI and z-DWI, elliptical ROIs were applied and manually drawn in way to cover the whole area of each tube. The circular ROI obtained on T2WI was copied and pasted onto the DWIs for the following analysis. Image distortion was quantitatively assessed on each tube including the saline and air by the following matching index between T2WI and DWI: [Matching index (%) = T2W-DWIoverlapping area / whole T2WI area]. Chemical shift (mm) was assessed on the oil tube and the difference of the center location was measured between on T2WI and DWI. *Patient Study:* Thirteen patients with known or suspected malignant lesions (61.9 ± 18.7 year-old, 7 males and 6 females) were included in this study. FDG-PET imaging, c-DWI and z-DWI were simultaneously acquired with the PET/MR hybrid system. C-DWI and z-DWI was performed in the trans-axial direction with FOV covering whole trans-axial body section for c-DWI and with RFOV covering lesion for z-DWI, respectively. PET/DWI fusion images were generated on the workstation. For PET imaging, ROIs for metabolic tumor volume were placed to include area of SUV more than 40% of tumor SUVmax. On DWI, ROIs were manually drawn along the border edge of high signal intensity area of tumors. Two radiologists performed visual assessment of PET/DWI registration quality using colored image fusion method. In addition, quantitative assessment was performed with the ratio of maximum overlapping area by the following matching index: [Matching index (%) = PET-DWI overlapping area / PET positive area]. Paired t-test was used for statistical analysis.

Results and Discussion: *Phantom Study:* As FOV along the phase-encoding direction decreased from 100% to 40%, the EPI factor decreased and receiver bandwidth increased (Table 1). Matching index (%) for saline and air tube was much better in z-DWI than in c-DWI, and gradually increased with %RFOV decrease (Fig. 1). The matching index for saline tube reached plateau with RFOV at 80%, while that for air tube kept improving as %RFOV decreased. Chemical shift seen in oil tube revealed no difference between c-DWI and z-DWI with 100% RFOV, and drastically improved as %RFOV decreased. These results indicate that z-DWI could improve image distortion even with 100%RFOV, and %RFOV as possible should be small as possible for lesions, especially when the lesions are surrounded by air. *Patient Study:* Twenty-one lesions positive in both PET and DWI with size larger than 50 mm^2 were included for analysis. Tumors were located in the region of head/neck (n =4), lung/mediastinum (n = 9), liver/pancreas (n = 4) and bone/soft tissue (n = 4). The mean EPI factor was significantly lower in z-DWI than c-DWI (45.4 ± 17.8 vs. 61.8 ± 12.0, $p < 0.001$). Registration quality with PET visually improved in z-DWI. In quantitative analysis, z-DWI improved segmentation accuracy in 19 of 21 lesions and the mean matching index obtained in z-DWI was significantly larger than in c-DWI (75.9 ± 20.0 % vs. 56.5 ± 24.1 %, $p < 0.01$). These results seem to be consistent with the previous reports[2] indicating that z-DWI with reduced EPI factor could improve image distortion in patients.

Conclusion: Zoomed DWI is useful to obtain more accurate registration of PET/DWI fusion imaging by reducing susceptibility artifact and image distortion.

	RFOV (%)	EPI factor	BW (Hz/pixel)
c-DWI	100	63	21.4
z-DWI	100	57	23.5
	80	47	27.8
	60	37	40.6
	40	27	54.4

Table 1. EPI factor and receiver bandwidth in c-DWI and z-DWI at different RFOV.

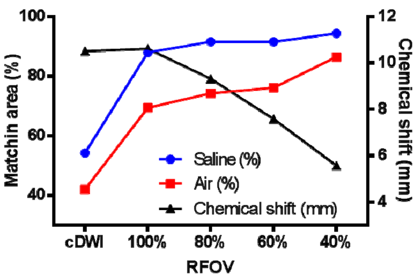

Fig. 1 Matching area between T2WI and DWIs and chemical shift with different %RFOV.

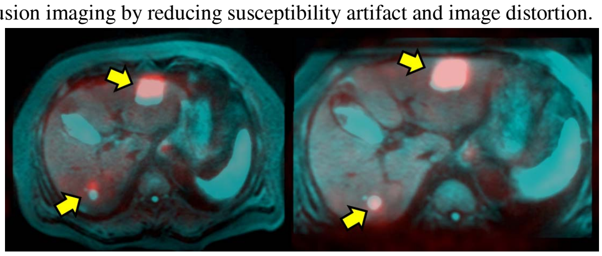

Fig. 2 Representative fusion images of c-DWI (left) and z-DWI (right) in metastatic liver tumors (arrows). Registration accuracy between PET (red) and DWI (cyan) improved in z-DWI.

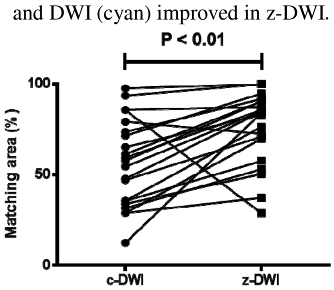

Fig. 3 Comparison of matching area (%) between c-DWI and z-DWI. P value, by paired t-test.

References: 1. Rieseberg S, et al. MRM 47;1186 (2002)
2. Riffel P, et al. Eur Radiol. 24;2507 (2014)