The Impact of Dixon Water-Fat Separation on Motion Correction in PROPELLER MRI

Michael Schär[1,2], Holger Eggers[3], Nicholas R Zwart[2], Yuchou Chang[2], Akshay Bakhru[4], and James G Pipe[2]

[1]Philips Healthcare, Cleveland, OH, United States, [2]Neuroimaging Research, Barrow Neurological Institute, Phoenix, AZ, United States, [3]Philips Research, Hamburg, HH, Germany, [4]Philips Healthcare, Bangalore, Karnataka, India

Purpose: PROPELLER[1,2] is an established method for motion insensitive MRI. A challenge in PROPELLER MRI is fat. Due to the difference in chemical shift between water and fat, fat is shifted radially over 180°. This water-fat shift (WFS) leads to blurring of fat in the reconstructed images. Additionally, the motion correction may reduce the fat blurring at the expense of water sharpness. To circumvent these effects, PROPELLER images are usually acquired with minimized WFS, i.e. maximized sampling bandwidth, leading to a low imaging efficiency. **In this work** we acquire data at two different echo times, interleaved in each shot, allowing Dixon water-fat separation[3,4] on individual blades. For each blade, the fat image can then be shifted back by the known WFS to its origin (corrected fat). PROPELLER images from blades with water only, corrected fat only, or water and corrected fat combined should not suffer from blurring even when data are acquired more efficiently with lower sampling bandwidth. The goal is to study the impact of the proposed correction on PROPELLER motion estimation.

Methods: Data were acquired in the head of one volunteer on a Philips Ingenia 3T scanner. A T2-weighted turbo-spin-echo PROPELLER sequence was modified to acquire each phase encoding step twice in a row, with all odd echoes sampling the gradient echo at the spin echo and all even echoes with the acquisition window shifted by $\Delta TE=1ms$. Hence each shot acquired the same blade at two different echo times and half of the turbo-factor phase encode lines. A SENSE[5] factor of 3 was applied to widen the narrow blades. Data were acquired with a WFS of 2.5 pixels and a turbo factor of 18 leading to a shot duration of 210ms. Other parameters were: FOV 250mm, voxel size 0.6mm, slice thickness 4mm, 30 slices, and an acquisition time of 3 minutes. Two datasets were acquired, one while the volunteer was holding still and one with small head motion every 10s. Each blade was unfolded with Cartesian SENSE and then water-fat separated[4]. Blades with water only, fat only, corrected fat only, water plus fat, and water plus corrected fat were fed into the PROPELLER algorithm[2] with rotation correction turned off to estimate shift corrections for each blade; and with neither rotation nor shift correction to determine blade weights based on cross-correlation values for each blade. Images were reconstructed with and without motion correction.

Results: Slices acquired at the level of the eyes and below have shifts of 1-2 pixels for the water plus fat blades, which is corrected well when adding corrected fat to water or using water only (Fig. 1A). Blades with corrected fat achieve higher weights compared to non-corrected fat (Fig. 1B). Those improvements are visualized in Fig. 2AB showing the difference between applying and not applying motion correction in data acquired without motion. Fig. 2C-E show that water-fat separation and motion correction perform well with the proposed method, and reconstructing images from blades with water only or blades with corrected fat reduces blurring compared to images reconstructed without correcting fat or without applying motion correction.

Discussion and Conclusion: Water and fat separation for each blade, and combining them again after shifting fat back to its origin, improves the shift estimates in PROPELLER MRI of the human head leading to higher blade correlation and sharper images. The proposed technique enables PROPELLER MRI with lower readout bandwidth and, hence, higher efficiency. If desired, water or fat only images can be generated.

Figure 1: (A) Estimated shifts and (B) blade weights averaged over all blades for each slice. (C) Slice locations, 29 at top of head. The estimated shifts for the fat only blades are close to the expected 2.5 pixels and are well reduced for the corrected fat blades.
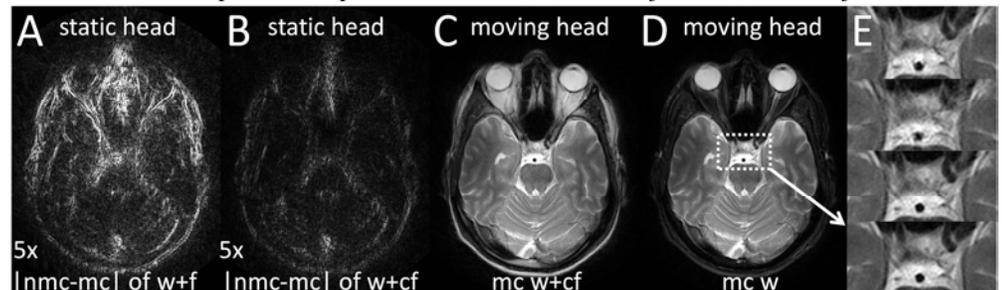
Figure 2: (A,B) Difference between images reconstructed with (mc) and without (nmc) PROPELLER motion correction using blades consisting of (A) water+fat (w+f) or (B) water+corrected fat (w+cf) acquired in a static head. Without correcting fat (A) the motion correction algorithm leads to more blurring. (C-E) Images acquired while the head was moving, reconstructed using proposed (C) w+cf blades and (D) water only (w) blades. (E) insets show reconstruction with (1st) w+f mc, (2nd) w+cf nmc, (3rd) w+cf mc, and (4th) w mc.

References: 1. Pipe JG. MRM 1999; 42:963-969; 2. Pipe JG. MRM. 2013 [Epub ahead of print]; 3. Dixon WT. Radiology 1984; 153:189-194.; 4. Eggers H. MRM 2011; 65(1):9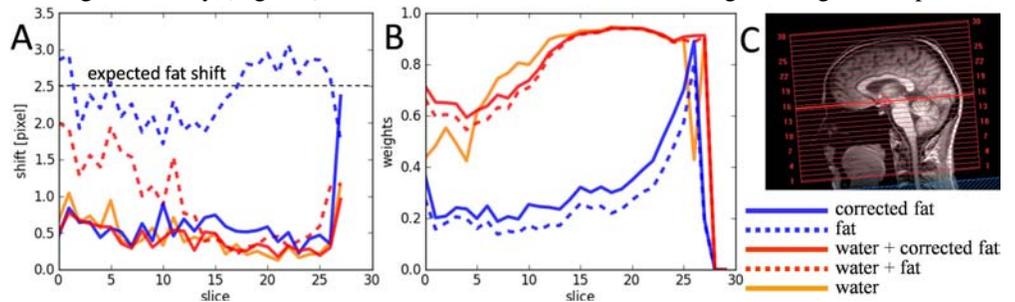6-107; 5. Pruessmann KP. MRM 1999; 42(5):952-62