Correcting artifacts in high temporal- and spatial-resolution dynamic abdominal studies using UNFOLD: A potential tool for improving perfusion quantification of DCE-MR investigations

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Introduction: In CT and MRI abdominal examinations, high spatial-resolution arterial and venous phase images are crucial for identification and characterization of liver lesions. Acquisitions of high-temporal resolution images in dynamic contrast-enhanced studies can be used to accurately quantify arterial perfusion in the liver. In this study, whole-volumetric high spatial-resolution images were acquired at a high temporal-resolution of 2s using the sliding window technique [1]. These images can be averaged together to produce high spatial-resolution multi-phase images for clinical use. **Un**aliasing by **F**ourier-encoding the **o**verlaps using the tempora**l** **d**imension (UNFOLD) is a method of separating aliased and nonaliased components in MR data [2]. The aim of this study was to investigate the capabilities of UNFOLD to correct for artifacts in whole-volumetric dynamic images of the abdomen. This has a potential for applications in dynamic studies of the liver which is an organ susceptible to motion artifacts even during a breath-hold.

Materials and Methods: Volunteer studies were performed on a 1.5T MRI system (Intera, Philips) using a phased array body coil and a T1-weighted gradient echo sequence. Imaging parameters were as follows: TR = 4.5 ms, TE = 1.1 ms, $\alpha = 24°$, FOV = 390 mm, RFOV = 70%, matrix size = 256/256, slice thickness = 7 mm. 12 dynamic images were acquired in a 23s breath-hold using a sliding window acceleration factor of 4 (i.e. a quarter of the k-space is sampled at one time point of the dynamic series). UNFOLD was applied to the dynamic datasets acquired using a low-pass Fermi filter with the form, $F(E) = 1 \Big/ 1 + \exp\left(\frac{E - E_f}{kT}\right)$. By interrogating the temporal spectra of the dynamic datasets, filter parameters of Ef = 0.005 and kT = 0.0001 were chosen for this study. This filter allows the central component of the temporal spectra to be passed through while it filters out the rest. The first three images in each dataset were discarded as they were reconstructed from incomplete k-space data. Difference images between original and corrected images were generated to help visualise the effects of UNFOLD-correction. Images in the original dynamic series were averaged and compared with individual corrected images, again, by means of difference images.

Results: In the example dynamic dataset shown (figures 1a and d show the seventh and eleventh images of the dynamic series, respectively), a brightening and darkening effect was observed within the aorta over time as a result of blood flow, together with artifacts caused by the pulsatile nature of blood flow and other physiological motion artifacts (e.g due to peristaltic motion). Results of the UNFOLD correction are shown in figures 1b and e, together with the corresponding difference images between the original and the corrected images (c and f). As a result of UNFOLD correction, blood flow brightening and darkening effects in the aorta through time were significantly reduced, so were the pulsatile flow ghosting artifacts which occured above and below the aorta. The correction effects can be visualized clearly in the difference images. An image averaged over the original dynamic series is shown in figure 2a. This would be equivalent to one of the high spatial resolution multi-phase images used in clinical contrast-enhanced MR studies. Difference between this averaged image and the seventh UNFOLD-corrected image is shown in figure 2b. It can be seen that a significant amount of artifact has been removed using UNFOLD.

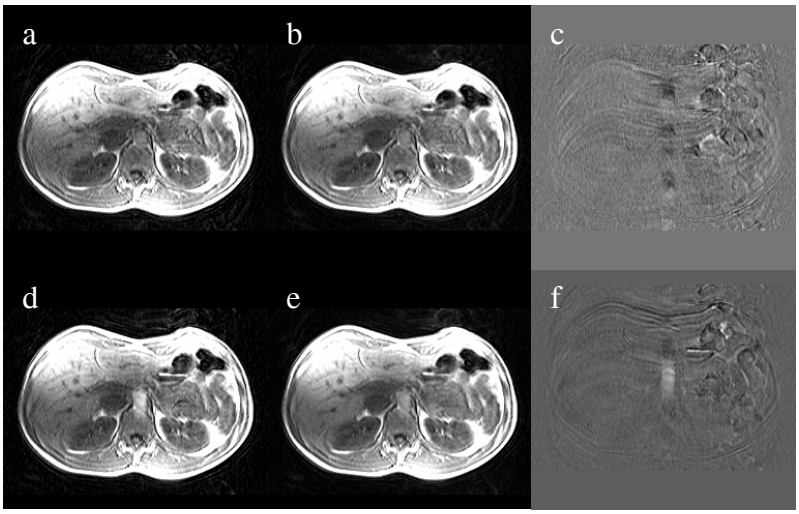

Figure 1: Results from the application of UNFOLD on the dynamic series. Only results of the seventh (a, b and c) and the eleventh (d, e and f) images of the series are shown. a) & d) Seventh and eleventh images of original dynamic series, respectively, b) & e) corresponding UNFOLD-corrected images and c) & f) difference images between original and corresponding corrected images. Original and corrected images have been windowed to a level which shows minor differences between the two. The correction effects of UNFOLD can be visualised clearly in the difference images. There is a visible reduction in blood flow artifacts and pulsatile flow ghosting artifacts.

Discussions & Conclusions: UNFOLD has effectively corrected both flow and motion artifacts in a dynamic series which was acquired in a breath-hold. UNFOLD enables visualisation of the right lobe of the liver which would otherwise be obscured by pulsatile artifacts. An issue associated with the applications of UNFOLD in dynamic studies is that data are modified by the filter (hence, corrected images are blurred). Simulation work is needed to quantify how much of the actual data are modified and whether it is justifiable to do so. This study has shown that artifact correction using UNFOLD is effective in a breath-hold study and has a potential for applications in dynamic imaging of the liver which is an organ susceptible to motion artifacts even in a breath-hold. Artifact-corrected, high-temporal resolution dynamic data can be used to accurately quantify arterial perfusion of the liver.

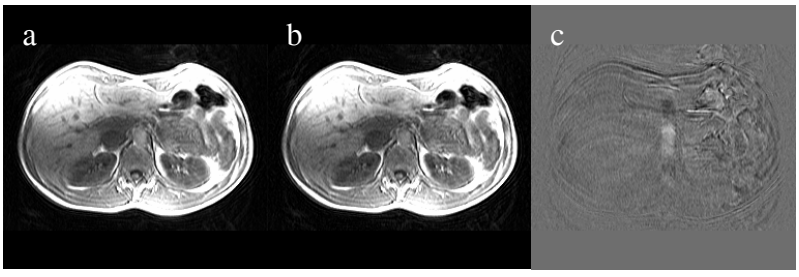

Figure 2: a) image averaged over original dynamic series, b) seventh UNFOLD-corrected image of dynamic series and c) difference image between the averaged original image and the seventh UNFOLD-corrected image.

Acknowledgements: This work was supported by Cancer Research UK (C1060/A5117) and EPSRC (GR/T20427/01)

References: [1] Rasche V, et al. Magn Reson Med 1995; 34:754-761, [2] Madore B, et al. Magn Reson Med 1999; 42(5):813-828.