Forward-field calculations improve contrast of unwrapped MR phase images

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INTRODUCTION The advantages of high field MRI include high spatial resolution and the increased quality of phase images [1]. However, the increased sensitivity to susceptibility effects leads to unwanted phase wraps, for instance those originating from air cavities, particularly in the frontal region of the brain. Standard phase unwrapping methods, such as high-pass (HP) filtering [2], prove sub-optimal in eliminating phase wraps with high spatial frequencies [3]. Forward-field calculations can be used to compute geometry-dependent artifact-corrected (GDAC) phase images in which the effect of these geometry-induced phase wraps is reduced significantly [3]. We have applied this technique to a high-resolution T2*-weighted sequence at 7T to study and quantify its effects on gray matter / white matter (GM/WM) contrast.

METHODS

Data acquisition Data were acquired using a whole-body 7T MR imaging system (Achieva; Philips Healthcare; Best; Netherlands) using a 16 channel receive array coil. A high-spatial-resolution T2*-weighted sequence was used with the following parameters: TR=750ms, TE=25ms and FA=45°. The sequence results in a nominal spatial resolution of 0.24x0.24x1.0mm (1024 x 1024 x 10 voxels) and scan duration of 9 min [1]. Two 3D T1-weighted sequences with TE=2.6ms and TE=3.6ms were acquired for segmentation of air-cavities (using the shorter echo time) and estimation of the phase response (using both scans). Imaging parameters were TR=5ms, FA=7°, a nominal spatial resolution of 0.7x0.7x0.7 mm (352 x 352 x 248 voxels) and scan duration of 8 min each.

Data processing The phase response corresponding to an approximate segmentation of air/tissue interfaces was computed using forward-field calculations [4] and used to correct the phase observed in the high-resolution T2*-weighted data. This forms the basis of the GDAC phase unwrapping method [3]. The T1-weighted sequence with TE=2.6ms was used to segment the air-cavities manually. The susceptibility difference between air and brain-tissue was estimated using the phase difference between the two T1-weighted datasets [3]. The simulated phase images were scaled and aligned to reflect the TE and the resolution of the T2*-weighted sequence. Finally the transformed phase was subtracted from the original T2*- data and subsequently unwrapped using HP filtering.

Evaluation protocol The HP-GDAC unwrapped images were compared to data unwrapped using the standard HP filtering technique. In addition the contrast between GM and WM was computed for both techniques.

RESULTS AND CONCLUSION The effects of using GDAC are shown in Fig. 1: given a kernel size *n* x *n*, images processed with HP-GDAC exhibit fewer remaining phase wraps than images processed using only HP filtering. However, the GDAC processing method does introduce some small artifacts originating from segmentation and susceptibility estimation errors. These are mostly visible in the posterior part of the brain. Despite those artifacts, a qualitative comparison between fully HP and HP-GDAC unwrapped images shows that the kernel size of HP-GDAC unwrapping can be much smaller to get a comparable wrap reduction as obtained with HP unwrapping. Because of the smaller kernel size, GM/WM contrast is significantly increased as demonstrated in Fig. 2. Therefore the GDAC technique results in a more favourable trade-off between unwrapping and GM/WM contrast.

REFERENCES [1] Duyn et al, Proc Natl Acad Sci 104,11796-801 (2007); [2] Wang et al, J Magn Reson Imaging 12, 661-70 (2000); [3] Neelavalli et al, J Magn Reson Imaging 29, 937-48 (2009); [4] Concepts in Magn Reson Part B (Magn Reson Engineering) 19B(1), 26-34 (2003).

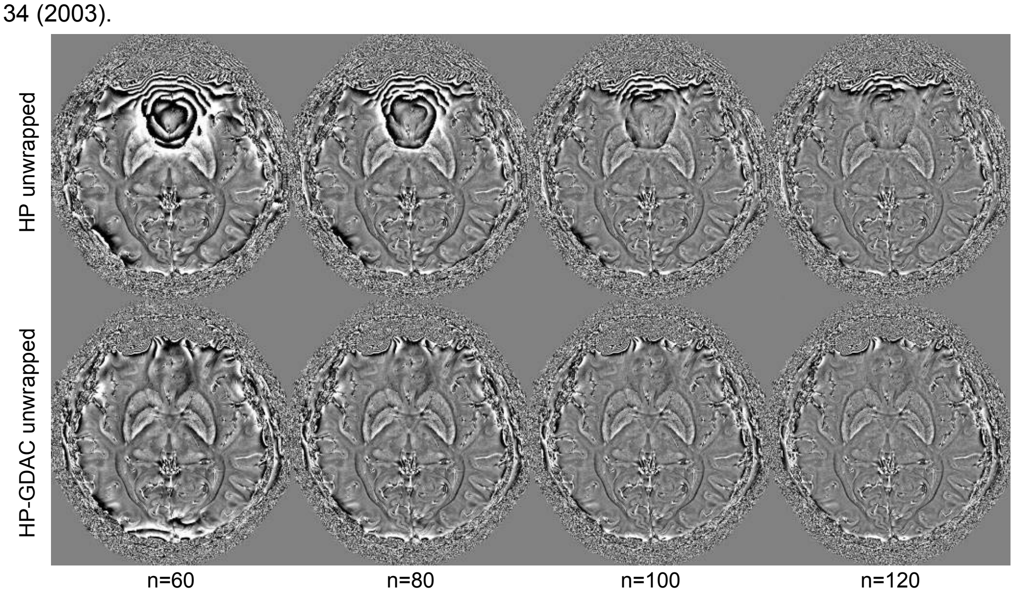

Figure 1: HP and HP-GDAC unwrapped phase images, given a kernel size *n*.

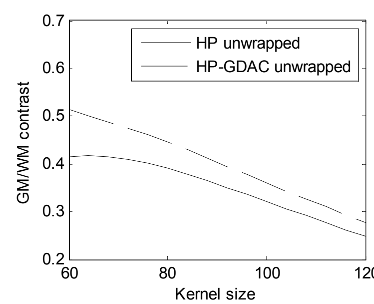

Figure 2: GM/WM contrast versus kernel size measured in a temporal region