Irretrievable signal loss in partial-Fourier acquired diffusion-weighted images

M. P. Zwiers[1], E. Visser[2], D. G. Norris[2], N. Papinutto[3], and B. A. Poser[2]
[1]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, -, Netherlands, [2]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, Netherlands, [3]Center for Mind-Brain Sciences, Trento, Italy

Introduction

Diffusion weighted (DW) imaging is highly sensitive for bulk motion, which frequently occurs in vivo, such as in the lower brain areas, where the parenchyma pulsates rhythmically due to cardiac activity. It is known that for partial-Fourier (PF) imaging, the emergence of pulsation artefacts in DW images depends critically on the image reconstruction method. Specifically, it has been shown that zero-padding PF reconstruction reduces pulsation artefacts compared to the Margosian method[1] and that homodyne PF reconstruction reduces these artefacts compared to full-Fourier (FF) reconstruction[2]. The current explanation is that cardiac pulsations give rise to high-resolution phase variations that are not accounted for by these PF methods' low-resolution phase estimates. More advanced reconstruction methods have been developed that provide better (high resolution) phase estimates. However, all PF reconstruction methods suffer from pulsation artefacts when low-frequency information is lost, i.e. they cannot recover the signal voids that are present when using zero-padding reconstruction (as it does not depend on the phase information). Thus, as it sets the bar for all PF methods, it is important to assess the resilience of the zero-padding method against cardiac pulsation artefacts. In this study we investigated this open question and quantified the amount of cardiac pulsation artefacts for various PF fractions. Furthermore, we used FF acquired data to retrospectively create PF data, as well as correct high-resolution (FF) phase images. These were used to study cardiac pulsation artefacts in ideal PF reconstructed images, i.e. using k-space conjugate synthesis[3] with the correct high-resolution phase demodulation.

Methods

Six healthy subjects participated in a DW-MRI experiment on a 3T TIM-Trio MR scanner. Phase and magnitude images were collected using a CP coil and the vendor's reconstruction methods (VB15). A single run consisted of three repeats of a twice-refocused DW sequence (TRSE-EPI; TR 5700 ms, TE 101 ms, 20 DW + 1 b0 acquisitions, b=1000 s/mm², matrix 88×88, 20 interleaved transversal slices, voxel-size 2.5×2.5×2.5 mm). Four runs were collected in each subject using a PF-factor of 5/8, 6/8, 7/8 and 1 in the PE direction. The non-acquired part of the EPI read-out was replaced with a silence (waiting) period to ensure that the sequence was not further optimized (changed) by the vendor's software routines. Cardiac pulsation artefacts were quantified using the PATCH method[4].

Results and Discussion

The number of detected cardiac pulsation artefacts was found to decrease rapidly with PF-factor (Fig.1). Pulsation artefacts emerge in areas with a negative phase derivative in the PE direction and lead to blurring of k-space (Fig.2). The pulsation artefact is much larger in the low-resolution magnitude reconstruction and now also includes areas with positive phase derivative (Fig.2). The retrospectively created and ideally reconstructed PF images showed very similar cardiac artefacts compared to zero-padding reconstructions (not shown). Taken together we conclude from our data that cardiac pulsations induce phase gradients in DW acquisitions that can shift the low-frequency information from these areas into the unacquired part of k-space. This intricate blurring act destroys the conjugate symmetry of k-phase, not only in phase but also in magnitude. The associated signal voids are therefore irretrievable by any PF reconstruction method. Thus, PF acquisitions in DW imaging should be avoided if one is interested in the pulsation susceptible brain areas or be used solely in a cardiac gated fashion.

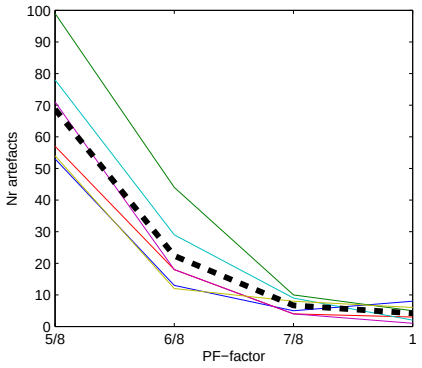

Fig.1. Individual and group average (dashed line) nr of cardiac pulsation artefacts

References

1. Robson and Porter, 2005. Magn. Reson. Imaging 23, 899-905
2. Chung et al., 2010. Neuroimage 49:631-40
3. Bernstein et al., Handbook of MRI Pulse Sequences, 2004.
4. Zwiers, MP. Proc ISMRM 2009;17:1423.

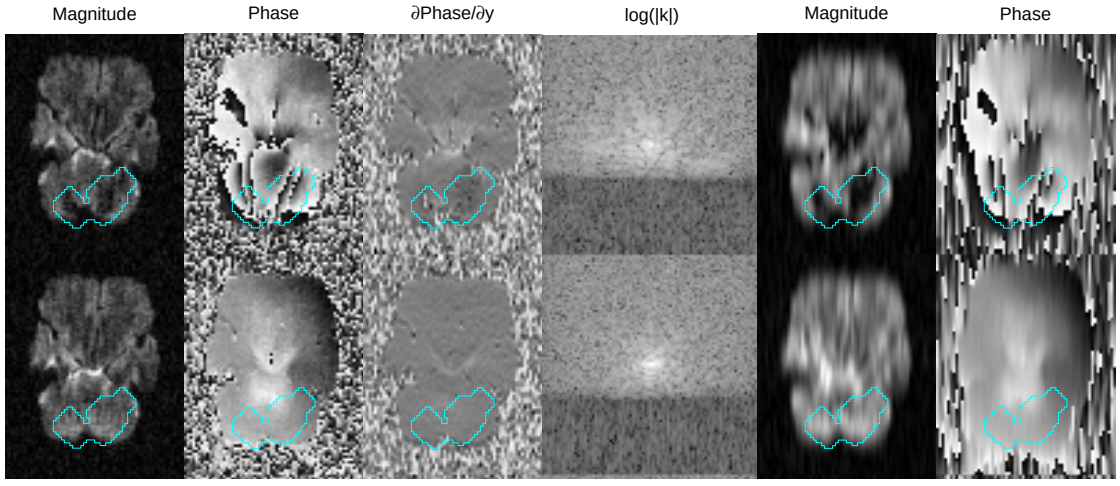

Fig.2. Upper row: Cardiac artefact in 5/8 PF images (col. 1-4) and in reconstructions from the symmetrically acquired central part of k-space (col. 5-6). Lower row: Repeated acquisition without cardiac artefact.