Effect of Trajectory Delay in Cine Ultra-Short TE Phase-Contrast MR Imaging of the Carotid Bifurcation

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Introduction

UTE phase contrast may be a more accurate technique for measurment of blood flow with higher Reynolds numbers and has previously been investigated for measurement of blood flow through the aortic valve [1]. Additional potential application areas for UTE PC MRI is measurement of blood flow in the presence of atherosclerotic disease where there is turbulent and disturbed flow distal to a stenosis. UTE can remedy intravoxel dephasing which leads to signal loss and reduce errors in velocity measurment . However UTE suffers from gradient channel delays that are typically negligible using TE > 1 ms. These delays can result in phase errors that may affect the accuracy and reliability of flow measurements. In this work we present a UTE-PC sequence to measure the disturbed blood flows and show that correction of these phase errors improves the result of UTE-PC technique dramatically. Here, the proposed sequence is utilized to quantitatively measure blood velocity in the carotid bifurcation which is associated with disturbed blood flow and results are compared to standard PC MRI sequences.

Method

UTE approaches enable very short TE acquisitions and centric-radial acquisitions. Center-out k-space lines in radial trajectories help reduce the effect of intravoxel dephasing and related phase artifacts by minimizing the first moment of readout gradient and oversampling of the center of k-space [2]. However center-out k-space lines are sensitive to phase errors due to gradient delays on physical gradients, eddy current, and B_0 field inhomogeneity. This can result in miscentered k-space trajectory and lead to image artifact and incorrect phase calculations. To reduce this phase artifact gradient channel delay should be characterized for each gradientdirection and corrected. This one-time calibration is done with a phantom scan prior to the in-vivo scan. The UTE-PC sequence was used to measure PC images in three directions by switching the flow encoding gradient between the three physical directions. The trajectory delay was measured for each direction using a phase-shift auto-correlation method and the measured trajectory delays were subtracted from each k-space trajectory in each direction. These trajectory delays were applied to all subsequent in-vivo scans, without changing any scanning parameters that may affect the gradient channel delays.

Imaging was performed on an Achieva 3T Philips scanner using a combined 18-element SENSE NeuroVascular coil capable of imaging carotid vessels from the aortic arch to circle of willis. The gradient channel delays were corrected using a phantom prior to scan and subsequently PC images were acquired ipsilateral to carotid bifurcation in an axial slice. A conventional PC MRI sequence with cartesian trajectory with TE/TR = 2.5/3.9 ms, FOV=180*200 mm, Venc=200 cm/s, spatial resolution=2.0*2.0*8.0 mm, flow encoding in the through-plane direction were used followed by proposed UTE-PC sequence with TE/TR = 1.09/6.2 ms, FOV=180*180 mm, Venc=200 cm/s, spatial resolution=1.17*1.17*5.0 mm, flow encoding in the through-plane direction. For each sequence four consecutive RF pulse and readouts were used to acquire flow sensitive images in three directions and one flow compensated (reference) image.

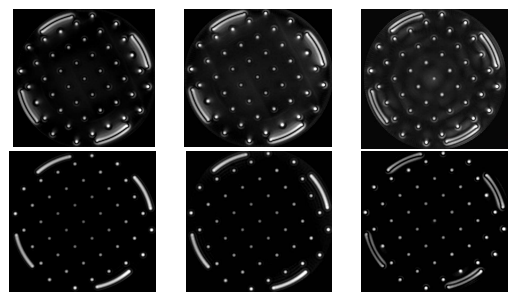

Figure 1:phantom result for different flow directions. The first row shows the original images using UTE-PC imaging in FH, AP, and RL flow direction respectively. The second row shows the result after miscenterd k-space correction using trajectory delays of 17, 20, and 30 for FH, AP, and RL flow directions.

Results

Figure 1 demonstrates results from a phantom study using UTE-PC sequence in three flow directions. The top row shows the three images with different flow directions without trajectory delay correction. The bottom row shows the images after calculation of trajectory delay and their subsequent application for each direction. The trajectory delays for each gradient channel are slightly different revealing that gradient delay in different physical gradient have different value.

A 29 years old volunteer was examined using both a standard PC MRI sequence and the proposed UTE-PC MRI sequence. Blood flow was evaluated in right internal carotid artery (RICA) ipsilateral to carotid bifurcation using both the standard and proposed sequences. Figure 2 demonstrates the peak velocity in RICA using conventional PC MRI and UTE-PC MRI with and without trajectory delay correction. Peak velocity for both standard and UTE-PC sequence with trajectory delay correction is ~ 37 cm/s but for UTE-PC without miscentered k-space correction is ~ 44 cm/s. It is also clear that peak velocity graph for UTE-PC with trajectory delay correction is similar PC MRI but for UTE-PC without trajectory delay correction is different at peak systole. Magnitude image for UTE-PC with trajectory delay correction shows less artifact compared to UTE-PC without trajectory delay correction.

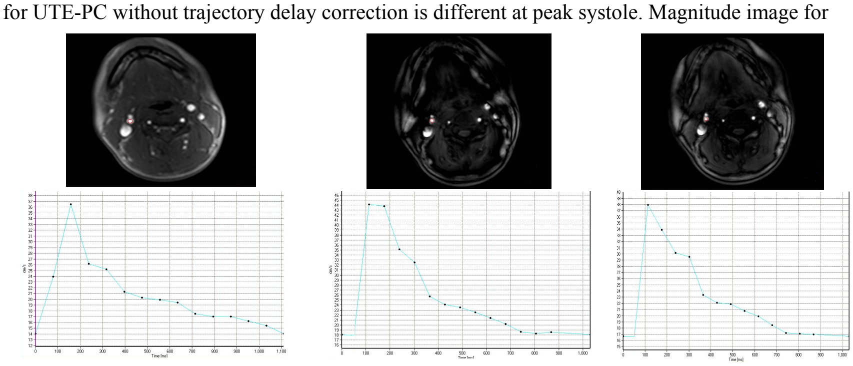

Figure 2: RICA peak velocity profile and magnitude image for conventional sequence (first column), UTE-PC MRI without trajectory delay correction(second column) and UTE-PC MRI with trajectory delay correction(third column). Peak velocity profile for UTE-PC MRI without trajectory delay correction is different with conventional PC MRI.

Conclusion

The present study demonstrates that careful gradient channel calibrations must be done to use UTE-PC MRI. We showed the potential capability of UTE technique for flow imaging using phase contrast. By using three trajectory delays in three gradient channel, k-space the trajectory delay artifact was reduced, resulting in more accurate and phase images were comparable to conventional PC MRI. This sequence could potentionally help to reduce signal loss due to disturbed and turbulant flow in carotid bifurcation in case of stenosis compared to conventional PC MRI.

References

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