3D Cine Ultra-short TE (UTE) phase contrast imaging in carotid artery: comparison with conventional technique

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Introduction

Phase contrast MRI is a non-invasive technique to assess cardiovascular blood flow. However, this technique is not accurate in cases where there is atherosclerotic disease and the blood flow is disturbed. Disturbed flow mainly can be seen at bifurcations, branch point, sharp bend and other regions of the arterial tree where the blood flow is altered. These areas are more prone to atherosclerosis and narrowing in vessels which leads to turbulent blood flow and a high velocity jet after stenosis. This results in velocity fluctuation leading to intravoxel dephasing and significant error in velocity measurement and assessment of blood flow. Carotid bifurcation is one of the main sites of atherosclerosis is and a good example of complex and disturbed blood flow due to atypical geometry of this branch site [1]. Therefore, conventional PC MRI at the site of carotid bifuraction suffers from intravoxel dephasing and flow artifacts. Previous studies have shown that short echo time (TE) has the potential to dcrease the phase errors [2]. In this work, a 3D UTE PC imaging method is designed to measure the blood velocity in carotid bifurcation using a center-out radial trajectory and short TE time compared to standard PC MRI sequences. With 3D UTE-PC combined quantification and visualization of blood flow in the region of interest is possible.

Method

In standard PC MRI sequences, slice excitation, rephasing, and velocity encoding gradients need to be applied before during TE. These gradients prolong TE and may lead to phase errors and velocity miscalculation. The UTE technique typically employs the following strategies to shorten TE: (i) it combines the slice select gradient with flow encoding/compensation gradient, (ii) it starts data acquisition from the beginning of gradient ramp using non-linear sampling. To further shorten TE, here we employ a 3D radial k-space sampling of FID using a non-selective hard RF block pulse without slice excitation. Ultra short TE techniques therefore achieve TE in the one milisecond or less range. The radial readout trajectory is based on radial traversal of evenly spaced k-space lines starting from center of k-space and ending on the surface of sphere with radius *Kmax* determined by spatial resolution. Center-out k-space lines in radial trajectories help reduce the effect of intravoxel dephsaing and related phase artifacts due to inherent minimization of first moment of readout gradient by oversampling of the center of k-space [3]. In the proposed 3D UTE PC method, non-cartesian "stack of stars" technique was applied.

Figure 1 shows the proposed sequence which includes a hard block radio requency (RF) pulse which was 0.5 msec. The TE time is defined as the distance time between the end of the RF pulse and beginning of readout gradient and ranges between 500-1000 usec according to the velocity encoding (Venc) determined by operator – this will permit a Venc up to 1000 cm/s. Sampling the k-space is started at the rising slope of readout gradient. Two back-to-back RF and readout gradients are used in order to construct one flow sensitive image and one flow compensated (reference) image.

Imaging was performed on an Achieva 3T Philips scanner using a combined 18-element SENSE NeuroVascular coil capable of imaging carotid vessels from aortic arch to circle of willis. Flow assessment was performed in carotid bifurcation on an axial 3D volume with 10 slices and a 3D slab thickness of 5 mm for each slice. Off-resonance error was corrected using a homogenous phantom which was imaged prior to scan for calculating the off-center k-space trajectory delay due to eddy current and gradient imperfection.Two sequences were employed: i) conventional 2-D Cine PC MRI sequence with cartesian trajectory with TE/TR = 2.5/3.9 ms , FOV= 160 * 188* 5 mm, Venc= 200, flip angle= 15, spatial resolution= 2.0*2.0*5.0 mm,flow encoding in the through-plane direction and ii) 3-D UTE-PC sequence with center-out radial trajectory with TE/TR = 1.09/6.2 ms , FOV= 170*170*40 mm, Venc= 200, flip angle= 15 , spatial resolution= 1.17*1.17*5.0 mm, flow encoding in the through-plane direction. The achieved acquisition window permits collection of 14 cine frames in one cardiac cycle for the UTE sequence. The number of phases acquired with the conventional sequence was 14 as well. The scan time for the conventianal sequence was about 2 minutes and for the proposed 3D technique about 4 minutes.

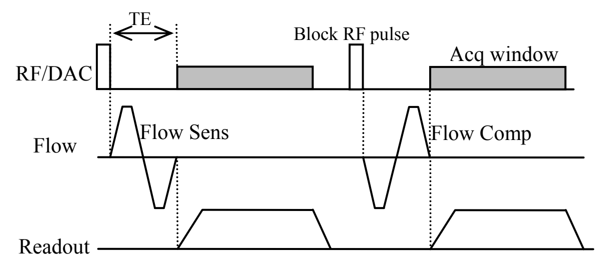

Figure 1: Proposed UTE-PC sequence. A flow sensitive and a flow compensated (reference) scan are acquired through application of a bipolar gradient after a block RF pulse.

Results

A normal volunteer (29 years old male) was evaluated using standard cine PC MRI sequence and proposed cine UTE-PC MRI sequence. Imaging was performed peripendicular to the common carotid artery covering an axial 3D volume from proximal to distal sections of the carotid bifurcation. Blood flow was evaluated in both the left common carotid artery (LCCA) proximal to carotid bifurcation as well as the right internal carotid artery (RICA) ipsilateral to carotid bifurcation using both the standard and proposed sequences. Figure 2 demonstrates the peak velocity in RICA and LCCA using these two techniques. Peak velocities in LCCA for both standard and UTE-PC sequence are around 50 cm/s and in RICA is around 37 cm.

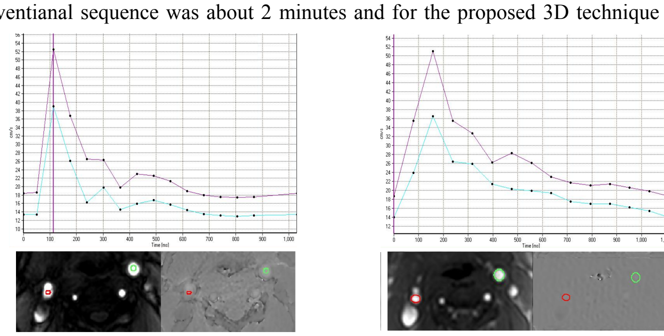

Figure 2: RICA and LCCA mean velocity profile, magnitude, and phase image for UTE-PC MRI (left) and conventional sequence (right).

Conclusion

The present study demonstrates that 3D cine UTE-PC MRI benefits from an ultra-short TE and higher spatial resolution compared to conventional 2D cine PC MRI. This 3D sequence enables comprehensive investigation of flow in carotid bifurcation and should provide more anatomical information as well as more accurate flow quantification and characterization, especially in the setting of atherosclerotic disease which can cause intravoxel dephsing and signal loss in flow images due to turbulence or disturbed flow. The achieved TE in the proposed method is ~ 1 msec which is shorter than previously published TE for assessing blood in carotid bifurcation (~ 3 msec) [4]. The proposed sequence will soon be tested in patients with Carotid disease.

References

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