A Novel Non-contrast MR Angiography Technique using Triggered Non-Selective Refocused SPACE for Improved Spatial Resolution and Speed

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Introduction: A non-contrast-enhanced MRA technique using gated 3D Turbo Spin Echo (TSE) has been reported for various clinical applications [1] [2], whereby systolic images are subtracted from diastolic images to provide high resolution MRA without exogenous contrast agents. Half-Fourier single-shot TSE results in a relatively long readout duration which causes vessel blurring due to T2 filtration effects and susceptibility to motion artifacts and arrhythmias. To reduce the long acquisition window for this cardiac imaging, one can use parallel imaging to reduce the acquired lines [3] and higher receiver bandwidth to reduce echo spacing time (ETS) [4],another potential solution to this limitation include multi-shot approach with the trade-off of increased scan time is less clinically acceptable especially as the technique is subtraction based and long scan times result in higher potential for motion between the corresponding systolic and diastolic scans.

As an approach to alleviating the spatial resolution limitations and to improve the reliability of this technique in fast heart rates we have investigated the use of a variable flip angle method for non contrast MRA using triggered 3D SPACE (**S**ampling **P**erfection with **A**pplication optimized **C**ontrasts by using different flip angle **E**volutions), which uses selective RF excitation, non selective RF refocusing pulses and variable flip angles for contrast manipulation [5]. To determine times of peak and minimal flow within the cardiac cycle, triggered (pulse or ECG) phase contrast flow measurements were performed. SPACE helps achieve lower SAR and shorter ETS of 2 ms, resulting in total acquisition windows of around 100ms, a slice turbo factor in 3D direction can be used to speed up the acquisition, because two or more partitions can be acquired in one cardiac cycle. Figure 1 shows the intrinsic contrasts mechanisms between the two techniques, TSE based approach uses C-A, SPACE based approach use B-A. We performed a comparison between the SPACE and the TSE based approaches in terms of spatial resolution and reduced blurring and small vessel conspicuity.

Materials and Methods: All experiments were performed with a 1.5 T Avanto system (Siemens, Erlangen, Germany), using a phased array peripheral angiography coil. 6 subjects were imaged, with ECG or pulse triggering. Phase contrast flow quantification with retrospective gating was used to determine trigger times for the "fast flow" and "slow flow". For MRA, a gated 3D SPACE sequence with 25% spoil gradient in readout direction was used with parameters FOV 440x440mm, slice thickness = 1.53mm, number of partitions=80, matrix =320x240, parallel factor 3, reference lines=24, total number of phase-encoding steps=56, BW=975Hz/pixel, TR = 2 R-R intervals, for single shot SPACE, TE=17ms,ETS=2.3ms ,TD (Trigger Delay) = 0 for slow flow (diastolic phase), and TD=280 ms for fast flow (systolic phase), Echo Train Duration = 56x2.3=128ms,Echo Train Duration 56x3.92=218ms; for single shot TSE,TE=50ms,ETS=3.92ms,TD=500ms,TD=250ms for fast flow, TD=450ms for slow flow, Echo Train Duration 56x3.92=218ms both use center reordering, total acquisition time around 2 min for each station.

Results: Representative results are shown in Figures 2 and 3. Figure 2 shows clear depiction of the entire arterial tree of a lower limb SPACE non-contrast-enhanced arteriography in a normal volunteer with 3 stations automatic patient table moving technique. Figure 3 showing the results in the acquisition windows decreased from 218ms to 128ms using 3D SPACE compared with 3D modified single shot TSE. Image quality was improved with 3D SPACE, particularly in terms of better depiction of small vessels, including distal branches and less blurring of large vessels with sharper vessel edges.

Conclusion: By shortening the acquisition window using the non selective refocus RF pulses, this new SPACE based MRA technique gives a narrower full-width at half maximum of the point spread function in phase encoding direction or less blur, compared to the conventional TSE sequence. The small branch vessels are depicted better because of the shorter ETS and a tighter readout gradient, therefore, the much shorter acquisition window, which keeps the acquisition window during systolic phase and results in less blurring and sharper edges of vessels, SPACE readout limits the duration of data acquisition during the cardiac/flow cycle – this enables more consistent discrimination of fast and slow flow – especially in compromised flow or fast heart rates and enables collection of high spatial resolution data sets in minimal time. In addition, the SAR issue is dramatically reduced by this technique. Moreover, the acquisition times can be much shorter than the conventional 3D TSE technique by using slice turbo factor 2 or more. These factors combine to provide a technique which (when compared to the Half Fourier TSE approach) is more robust, of higher spatial resolution, suffers less T2 filtration – (improved point spread function) and consequently demonstrates improved small vessel conspicuity.

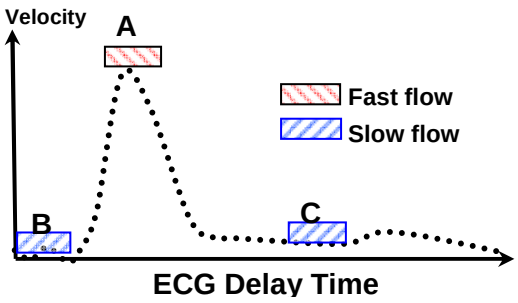

Figure 1: Intrinsic contrast mechanisms: TSE based approach uses C-A, SPACE based approach uses B-A.

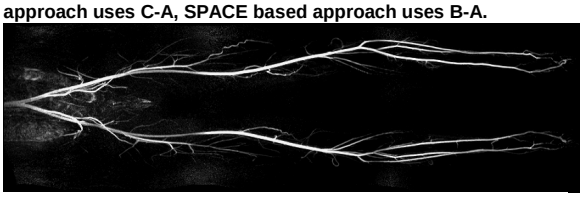

Figure 2- Lower Limb SPACE non-contrast-enhanced arteriography in a normal volunteer showing clear depiction of the entire arterial tree

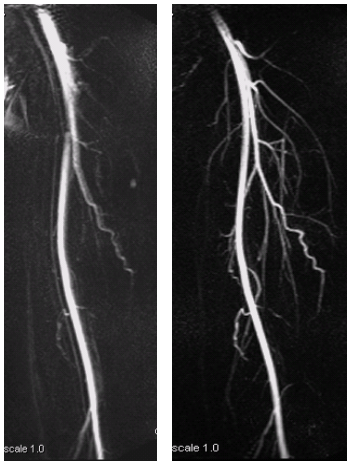

Figure 3- Single Shot TSE vs. Single Shot SPACE with matching parameters show decreased blurring and improved small vessel conspicuity in the left superficial artery and profunda branches

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