"Flow-void Enhanced" Volumetric Black-blood Angiography Using 3D-TSE with Very Low-constant Refocusing Flip Angles and Sensitized Flow Compensation

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Introduction:

3D RARE (TSE, FSE) techniques are promising for black-blood angiography [**1**]. Furthermore, RARE with variable flip refocusing enables acquisition of 3D T2-weighted imaging is used recently [**2**]. However, variable- or low flip refocusing pulses were used, vascular and CSF may appear dark in certain areas where flow may be considerable [**3.4**]. In this study, explore the sensitivity of low flip refocusing and "flow-compensation" to flow. In addition, we propose a new scheme of sequence parameter optimization for "flow-void enhanced" Volumetric Black-blood Angiography.

Methods:

The study was approved by local-IRB. All experiments were performed on a 3.0T whole-body clinical imager (Achieva, Philips Healthcare).

Phantom study: All data were acquired in one-dimensional fourier-transform (1DFT) mode using a 2D single-shot TSE with refocusing flip angle control, which to assess the effect of refocusing flip angle schedule and flow compensation on signal intensity changes of flowing spins. Moreover, we used a flowing phantom with roller pump (Multiflow Roller Pump Module 10H Series, Stoeckert-Shiley). The examined imaging parameters were: 1) Refocusing flip angles (180˚,90˚,60˚,30˚ used), 2) Pseudo steady-state preparation (Ninety-Plus-Half-Alpha: NPHA (90˚excitation-"90+α/2"-α-α-α-α-) **[5],** Asymptotic preparation (90˚excitation-α1-α2-α3-α4-α-α-) **[6]**, 3) Flow-compensation and imaging planes: Conventional FC (1-2-1 gradient moments in readout direction) or "Sensitized" FC (bipolar gradients in phase direction) added-sequences used at the "through-plane flow" and "in-plane flow" imaging planes. Moreover, additionally examined that in parallel or vertical direction of flow and phase-encode at the "in-plane flow" imaging planes.

Volunteer study: All volunteer experiments were acquired using a 3D **V**olume **IS**otropic **T**SE **A**cquisition (VISTA) with refocusing flip angle control. The examined imaging parameters were: refocusing flip angle, and flow-compensation with imaging plane, to optimization of clinical use.

Results and Discussion:

1) Refocusing flip angles: The low-constant refocusing flip angles were flow-void in early point of echo trains. Moreover, this result depended on a refocusing flip angle, and flow velocity **[Fig.1]**. As this reason, low refocusing flip angles were phase-dispersion accelerated from flowing spins. Therefore, a very low refocusing angle should be chosen for slow-velocity flow signal suppression.

2) Pseudo steady-state preparation: NPHA was more rapid flow-void in early point of echo trains than asymptotic preparation. As this reason, NPHA is more "dynamic" flip angle changes than asymptotic preparation.

3) Flow-compensation and imaging plane: At the "through-plane flow" imaging plane, conventional FC sequences were more flow-void than sensitized FC sequences. While, at the "in-plane flow" imaging plane, sensitized FC sequences were more flow-void than conventional FC sequences, and that were mostly effective in parallel direction of flow and phase-encode **[Fig.2]**. As this reason, combination of sensitized FC with very low refocusing flip angles were like a "phase-dispersion gradient" in at the phase-encode direction.

On the whole, optimal parameter for black-blood angiography was 1) very-low refocusing flip angles (30˚), 2) choose NPHA pseudo steady-state preparation, 3) "sensitized" flow-compensation at the "in-plane flow" imaging plane, that was more flow-voided in parallel direction of flow and phase-encode. **Fig.3** shows the carotid artery and intracranial black-blood angiography by "optimized" 3D-VISTA Black-blood sequences.

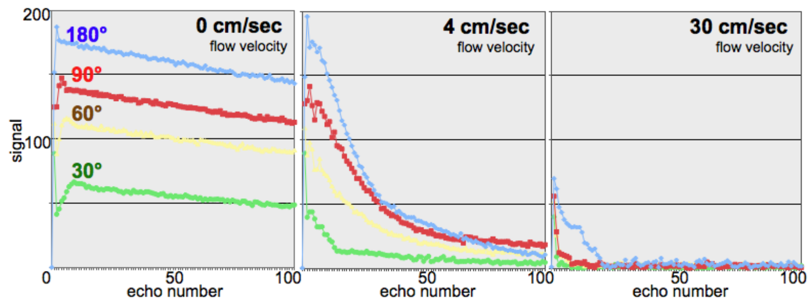


Fig. 1
Influence of refocsing flip angles and flow-velocity in signal behavior of echo train. (left to right : flow-velocity = 0 (static water), 4, 30 cm/sec)

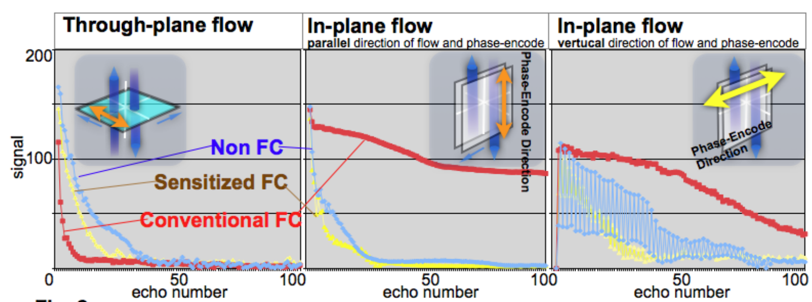
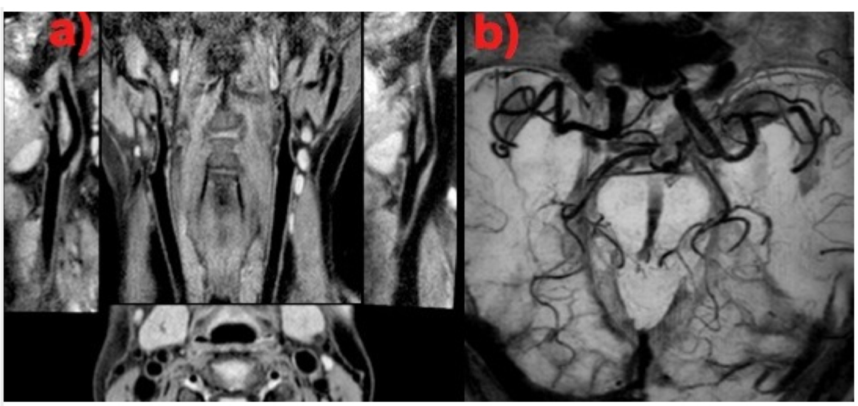


Fig. 2
Influence of flow-compensation and imaging plane (through-plane flow, and in-plane flow (parallel or vertical flow in PE) in signal behavior of echo train.

Conclusion:

This study showed the sequence parameter optimization for sequence-endogenous flow-void enhancement. This optimal sequence can be used for 3D volumetric black-blood angiography and vessel wall imaging. And may also be used for scan plan localization, and potentially plaque detection. Further investigation is needed for contrast parameter optimization (T1W, T2W,,,), and clinical evaluation and limitation.



References:
(1) Alexander, MRM 40:298-310 (1998) (2) Hennig, MRM 49:527-535 (2003); (3) Madhuranthakam, Proc ISMRM 15, p2523 (2007); (4) Busse, Proc ISMRM 14, p2430 (2006); (5) Hennig, MRM 44:983-985 (2000); (6) Alsop, MRM 37:176-184 (1997).

Fig.3
Carotid artery**[a]** and intracranial black-blood angiography**[b]** by optimized 3D-TSE (VISTA) black-blood sequences.
Imaging parameters were: TR=1500ms, TE=32ms, echo-spacing=4.6ms, refocusing FA=30deg, "90+alpha/2" pseudo steady-state preparation, ETL=70, and sensitized flow compensation used.