Non contrast MR Angio by intrinsic dephasing of true FISP SMS: Ssfp Minus Ssfp

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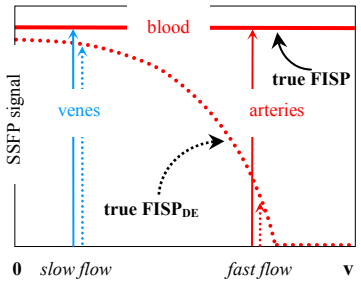
Introduction:

Contrast enhanced MRA is widely used due to the large blood signal, the fast acquisition and decreased motion artifacts at high spatial resolution. Very fast sequences and a proper timing of the high dose contrast bolus with the data acquisition, allows the separation of arterial from venous blood vessels. However, in patients with high risk for developing NSF (Nephrogenic Systemic Fibrosis), ce-MRA needs to be avoided. Non-ce MRA techniques can be performed in this group of high-risk patients. Now, new applications will broaden the spectrum of non-ce MRA. There are some alternative techniques: Time-of-flight MR Angio (ToF-MRA) is a noninvasive scheme exploiting the inflow of unsaturated spins perpendicular to the 3D volume, for the application of peripheral vessels a time consuming multi stack measurement is necessary. Phase sensitive methods needs a priori knowledge of the velocity range to avoid phase wrapping of the vessels to be imaged. Here we propose a SSFP (Steady State Free Precession) sequence scheme which is based on the intrinsic very high signal sensitivity of flow phase instabilities from TR to TR interval. It does not need any kind of gating or triggering to separate veins from arteries needed as in non-ce MRA methods like Fresh Blood Imaging FBI [1].

Materials and Methods:

By a train of n rf pulses under the condition TR < T2 a steady state magnetization is formed. If a position dependent phase $\Phi(n)$ is accumulated during the n^{th} TR interval and if it changes nonlinearly with n, the SSFP signal can be completely destroyed [2]. This signal behavior is easily seen on images from non-balanced SSFP sequences like the FISP (S+) or the GRASS type. In the cervical neck region, even very low CSF pulsations leads at a distinct velocity value to a complete signal break down of the fluid signal; in that manner the incoherent flow pattern acts like an efficient rf-spoiler. This behavior is utilized in a trueFISP sequence by a simple additional time gap Δ between the end of the read out gradient and the rewinding gradient pulse. Hereby the first moment M1 is no more zero at the end of the TR interval: M1(TR) # 0. The asymmetric 1 : 2 : 1 bipolar gradient scheme of balanced sequences is no more effective for moving spins, this is related to dephasing effects in phase encoding direction [3]. The standard trueFISP sequence is not flow compensated at the echo time TE = TR/2, but even for high velocities the intra-voxel dephasing is small because of the very short TE time [4][5]. Measurements were performed on a 1.5T MAGNETOM Avanto scanner (Siemens, Germany), using a 6 channel body array coil. Imaging parameters were typically Δ = 0 ms and Δ = 1.8 ms, TR= 6 ms = const., slice thickness = 1.8 mm, field of view = 400 mm^2, matrix 220p x 512 with partial k-space, TA = 48 sec for each 3D Volume. The sequences utilized, are depicted in Fig.2. Pixelwise, weighted subtraction of appropriated data sets, delivers the separated vessel images.

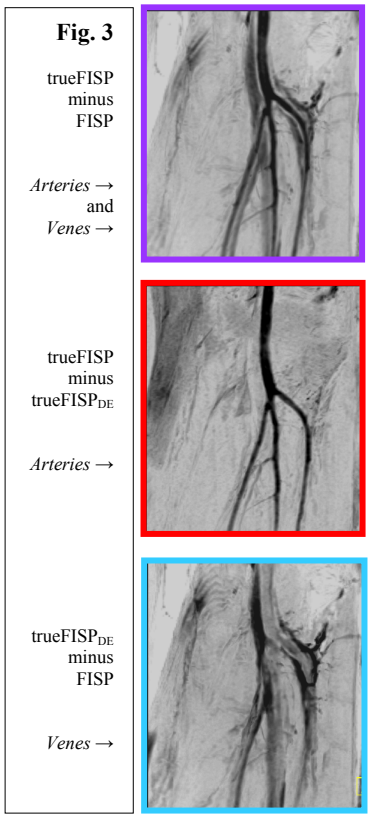
Fig. 1 Principle of the SMS method



Results and Discussion:

A knee study of a volunteer with the SMS method is depicted in Fig.3. Examples of the possible SMS subtraction combinations are shown. To increase dephasing effects, the same Δ value might also used in the phase and slice encoding direction. An slightly asymmetric readout of the echo helps also to enforce the signal destruction. In summary, we have shown that non-contrast enhanced peripheral 3D MR Angio imaging is possible within 1.6 minutes, without the need of any physiological triggering or gating.

Fig. 3



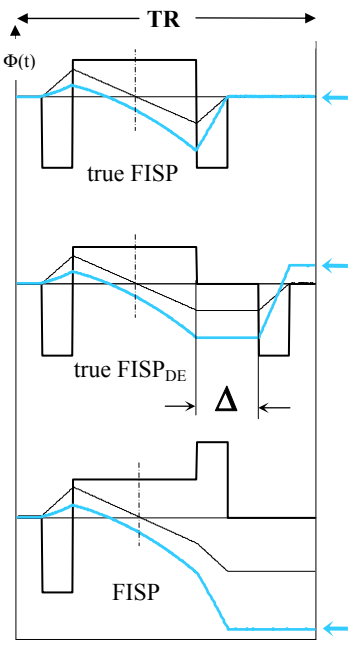


Fig. 2 Phase development in read out direction: $\Phi 0(t)$ for stationary- (**black**) and $\Phi 1(t)$ for flowing spins (**blue**)

$\Phi 1(t) := 2 \cdot \pi \cdot \gamma \cdot v \cdot M1(t)$ with $M1(t) := \int_0^t g(\tau) \cdot \tau \, d\tau$ the first moment M1.

- Rephased true FISP (standard)
- Dephased true FISP (modified)
- FISP (standard)

Identical TR times are used for both balanced sequences to keep off resonance effects constant.

Conclusion:

The results of this SSFP based subtraction technique, demonstrate the feasibility of peripheral imaging with a slightly modified standard trueFISP sequence. This SMS technique does not use triggering or gating and is used without any exogenic media. Parameter and sequence modification are needed to optimize this potentially useful method.

References:

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