Application of T-SLIP MRI sequence in the diagnosis of vascular abnormalities - preliminary results

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Learning objectives

T-SLIP (Time spatial labeling inversion pulse) is a relatively new and promising method for non-contrast MR-angiography. Time-SLIP is a non-contrast MRI technique that provides bright blood in vessels. Time-SLIP is a variant of an arterial spin labeling (ASL) technique and utilizes a selective suppressed pulse for label the blood as it flows into or out of an imaging region. Non saturated blood inflow into region suppressed by Inversion Pulse and demonstrated high signal of blood pool. The protocol was introduced in our clinic in 2014 in order to improve the level of vascular disease diagnostics. We have demonstrated the ability to enhance the MR-angiography by changing BBTI parameter (black blood time inversion - time for the inversion pulse). We have also compared the T-SLIP pulse sequence (PS) with the widely used 3D-TOF PS.
Background

T-SLIP sequence allows scanning almost all anatomical areas of the human body in vascular diagnostics - both large vessels, such as neck vessels [1], chest vessels [2], abdomen vessels (including portal system [3]), hepatic artery [4], renal artery [5], and vessels of the limbs, include small peripheral vessels [6].

All studies were performed on an 1.5 Tesla MR unit (Toshiba Excel ART Vantage, Japan), sequence battery included T1, T2 (including Fat Sat), T2* (neck region) weighted images, 3D TOF angiography (neck region), T-SLIP sequence: BBTI (Black Blood Time Interval). time between application 180 deg. pulse and start reading sequence was 1200 ms, varying from 900 to 1500 ms, reading sequence based on 3D SSFP, TR 5.2 ms, TE 2.6 ms, MA 256x256, 40 images with 2 mm thickness. Cardiac synchronization (peripheral pulse) was needed at neck region; respiratory synchronization was needed at abdomen region.

21 patients aged 29 to 75 years were analyzed with the T-SLIP technique: 14 of them underwent the examination of a neck artery (6 - with 3D-TOF); 6 patients - renal arteries; 1 patient - abdominal aorta. Some patients were already diagnosed, others demonstrated unknown vascular changes. As the result, we have found that in some cases T-SLIP angiography can replace classical angiography and it provides enough data for diagnostics by a specialist. In some cases additional 3D TOF angiography was performed because high resolution images was needed.
Findings and procedure details

Fig.1 a,b shows images (MIP postprocessing) taken on a 50 years old male patient with an additional S shaped bend of the left internal carotid artery, a) - T-SLIP, b) - 3D TOF images. Tortuosity visualized better on 3D TOF images despite the higher noise. Relative contrast and contrast /noise ratio were compared to 3D TOF and T-SLIP modes are presented in Fig.2. For T-SLIP (vs 3D TOF) relative contrast (Fig.2 a) of above 16%, the ratio of the contrast /noise ratio (Fig.2 b) is above 29%.

Vascular pathology was detected in 14 patients. The most significant findings are presented below for the understanding of the method.

Patient female, 79 years old, suffers from chronic renal failure and post-inflammatory atrophy of the kidney on two sides (more expressed on the left side) Fig.3 d,e,f. Surgeons discussed the viability of the left kidney and the presence of bloodstream in it. Contrast enhanced MDCT examination was contraindicated due to the high level of creatinine. By using different BBTI (900ms, 1200ms, 1500ms) it was found that in a small time (900 ms) BBTI left renal artery was not visualized at all (Fig.3 a). By increasing the BBTI (1200ms and 1500 ms) artery visualization was possible, what indicated the viability of the kidney and a present of low level of blood flow through it (Fig.3 b,c). In this case non invasive T-SLIP MR angiography with different BBTI parameter provided additional information for the clinical analysis of kidney function.

The female patient, 68 years old, suffering from high renal essential hypertension The retroaortal location of the left renal vein (Fig.4 b), flowing into the v.cava inferior by two vessels (Fig.4 c), as well as stenosis of the left renal artery (Fig.4 a,d) was detected in the patient with essential hypertension. Lower saturation region has been removed for clearer visualization of the inflow saturated spins of the left renal vein into v. Cava inferior. You should also pay attention to the artifacts along the vertical direction characteristic 3D SSFP associated with the sensitivity of the PS to the inhomogeneous gradient fields (Fig.4 a).

The female patient, 57 years old, was directed by a surgeon with a tumor of the neck. The tumor was detected by ultrasound scan. We scanned this patient, using T-SLIP together with 3D-TOF (Fig.5 a,b,d). Neck chemodectoma with a solid and cist components (Fig.5 c,e) was diagnosed (verified later). T-SLIP study helped to determine the effect of tumor mass on the neck vessels, as well as the blood supply to the tumor, which is important for the planning of neurosurgical interventions (Fig.5 a,b). It was indicated that the tumor was connected with external and internal carotid arteries. However, small collaterals were better visualised by scanning 3D-TOF (Fig.5 d), which is probably due to the specific feature of the method and T-SLIP blood flow sensitivity dependence on the BBTI.
The impediment to T-SLIP studying the abdominal vessels was indicated for patients with incorrect respiratory synchronisation, as an example Fig.6 a. In this case it is necessary to perform additional scans with the breathing synchronization to reduce artifacts. This extends time scanning. It proved that the use of T-SLIP is impossible for people with arrhythmia as T-SLIP scanning is synchronized with the pulse rate which is more important to scan the neck vessels (Fig.6 b).
Fig. 1: Patient male, 50 years old with an additional S shaped bend of the left internal carotid artery, MIP images, a) T-SLIP, b) 3D TOF images. Tortuosity visualized better on 3D TOF images despite the higher noise.

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Fig. 2: Comparision of relative contrast and contrast /noise ratio for T-SLIP vs. 3D TOF modes.
Fig. 3: The patient female, 79 years old, suffers chronic renal failure and post-inflammatory atrophy of the kidney by two sides, more marked on the left (More detail in the text).
**Fig. 4:** The patient female, 68 years old, suffering from high renal essential hypertension. The retroaortal location of the left renal vein (Fig. 4 b), flowing into the v.cava inferior by two vessels (Fig. 4 c), stenosis of the left renal artery (Fig. 4 a, d).

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**Fig. 5:** The patient female, 57 years old, with a tumor of the neck (chemodectoma). More detail in the text.

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Fig. 6: The impediment to T-SLIP studying the abdominal vessels with not correct respiratory synchronisation, as an example a), low T-SLIP image quality of the neck for patient with arrhythmia b).

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Conclusion

- Noninvasive T-SLIP angiography is a highly efficient scanning method which can be used in clinical practice for providing additional functional information. Compared with the 3D-TOF MR angiography, it possesses better characteristics of image: relative contrast (above 16%) and contrast /noise ratio (above 29%).

- The most informative results of using T-SLIP are obtained when visualizing the large vessels, which should be considered when choosing patients for the investigation.

- At the same time, this method has specific limitations: it is impossible to use the method for patients with arrhythmia (neck region) and non correct breast syncronisation (abdomen vessels). We have also observed artifacts associated with the magnetic field inhomogeneity and relatively low spatial resolution.
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