Non-Contrast-Enhanced Renal MRA using time-spatial labeling pulse (t-SLIP) with 3D balanced SSFP

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PURPOSE

Based on arterial spin labeling (ASL), a time-spatial labeling inversion pulse (t-SLIP) technique with 3D half-Fourier FSE was reported using a free hand spatial selection and tag-on and tag-off alternating scan, auto-subtraction, and MIP processing to only depict the marked blood while canceling the background signals at any specified inversion time (TI) [1]. The t-SLIP technique was also applied in a portal vein study to identify the blood flow pattern from the superior mesenteric vein and the splenic vein [2, 3]. Then, the t-SLIP technique was combined with a 3D balanced SSFP (b-SSFP) sequence employing parallel imaging to depict the vasculature from the aortic arch to the carotid arteries [4]. The goal of this study is to develop a reliable and practical non-contrast renal 3D MRA technique, which can be acquired within a reasonable scan time. Furthermore, optimization of technique by means of varying TI times, flip angle, and the number of segmentations for fat suppression, were performed to depict the renal artery branches.

MATERIALS and METHODS

The b-SSFP sequence provides high contrast between blood and background signals and also allows depiction of blood flow in all orientations. The t-SLIP pulse was placed to mark the aorta which flows directly into the renal arteries. In addition, the t-SLIP pulse was used to null the background signals. For suppression of venous flow, an inferior sat-band pulse was applied. In order to acquire data in a relatively short scan time, only a tag-on pulse was used with respiratory gating and parallel imaging. To optimize the image quality, TI times were varied to identify the null point for background signals and to study the travel distance of marked blood to the renal arteries. Secondly, an optimized flip angle of b-SSFP was studied to obtain good blood-to- background contrast. Thirdly, the fat suppression effect was evaluated by means of varying the number of segmentations used in the interleaved ordering from the center of k space.. All experiments were performed on 9 healthy volunteers and 10 consecutive patients using a clinical 1.5-T system, equipped with a parallel imaging torso coil. Typical axial acquisition parameters were as follows; TR/TE=5.0/2.5 ms, FA= 60-120 deg., matrix=256x256 (interpolated to 512x512), thirty 3-mm section slices (interpolated to sixty 1.5-mm slices), resolution of 0.6x0.55/1.5 mm after interpolation, respiratory triggering, parallel reduction factor=2.0, TI=700-1700 ms, 1-4 segmentations, CHESS fat suppression, and a total scan time of 3 to 5 min, depending upon the respiratory cycle.

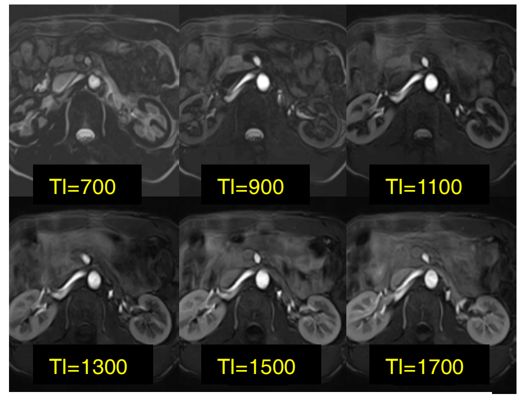

Fig. 1 Source images with various TI times.

RESULTS and DISCUSSION

Figure 1 shows the result of various TI studies acquired in the axial plane. In the TI=700 ms image, the aorta and the renal arteries have low signal intensity, meaning blood flow had not traveled far enough to image the renal region sufficiently; whereas, in the TI=1700 ms image, the blood signal is low due to the blood traveling a further distance. Note that the cortex signal is null at TI=700 ms and the medulla is null around TI=1100 ms. The aorta and renal arteries are depicted with the highest signal intensity between TI=1100 to 1500 ms. The background signals start recovering after TI=1500 ms. Figure 2 shows the signal intensities of various regions vs. different TI times. As TI time is increased, the background signals from the medulla, cortex, and liver begin to recover. Around TI=1100 ms, images show the highest contrast between the blood and medulla/cortex. Since most of renal branches are located in the medulla/cortex region, the contrast between blood and medulla/cortex was highest at this TI time. Figure 3 presents a typical axial and coronal MIP images on a volunteer. Figure 4 presents rotated coronal MIP images obtained on another volunteer. For the flip angle of b-SSFP, a 120-degree pulse gave the highest contrast between blood and background signals. For fat suppression, increasing the number of segmentations means increasing the number of fat suppression pulses per image; therefore, better fat suppression can be achieved as a result. However, the trade off to increasing the number of segmentations is an increase in the scan time. The scan time doubles from 1 to 2 segmentations or 2 to 4 segmentations. In our result, the segmentation of 2 allows reasonably good fat suppression while maintaining scan times around 3-4 min depending on the respiratory cycle time. Among 9 volunteers and 10 patients, 17 studies gave a similar result. However, two cases showed poor image quality due to motion artifacts.

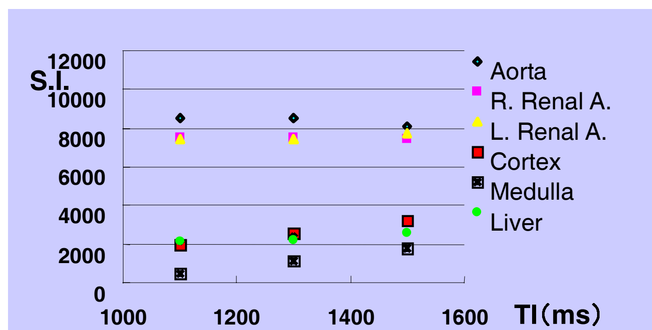

Fig. 2 Signal intensities vs. TI times.

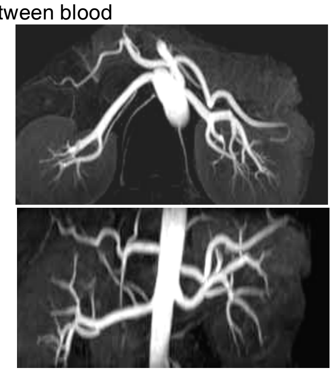

Fig. 3 Typical axial and coronal MIP images of non-contrast-enhanced renal MRA obtained on a volunteer using TI=1300 ms. Note that signal intensities from the aorta to the small branches of the renal arteries are conspicuously depicted.

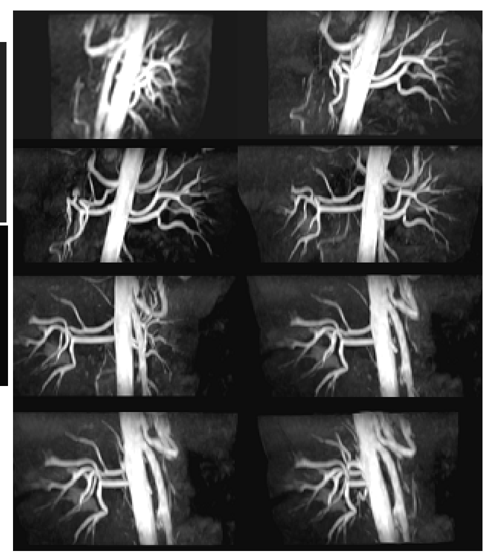

Fig. 4 Rotated coronal MIP images using TI=1100 ms.

CONCLUSION

The non-contrast-enhanced t-SLIP with 3D b-SSFP technique employing respiratory gating and parallel imaging techniques provides good quality MRA images from the aorta to the renal artery branches within a reasonable scan time. The technique is simple, robust, and easy to apply to the renal MRA examination and serves as a useful tool for screening procedures.

REFERENCES

1] Kanazawa H, Miyazaki M, ISMRM p140, 2002. 2] Ito K, et al, AJR 178:343-348, 2002. 3] Tsukuda T, et al, JMRI 22:4,527-533, 2005. 4] Yui M, Miyazaki M, et al., ISMRM p2121, 2004.