Non-contrast-enhanced MR angiography of the renal arteries with inversion-prepared b-SSFP: A comparison of different imaging protocols

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INTRODUCTION: Inversion-prepared b-SSFP imaging is a common technique for non-contrast-enhanced (non-CE) MR angiography (MRA) of the renal arteries [1-5]. With this method, a slab-selective inversion of the volume of interest is followed by a delay TI and subsequent data acquisition. While inverted stationary tissues recover during TI and appear with low signal, non-inverted blood enters the labeled region and is captured with high signal. Typically, a transverse inversion slab is used for spin-labeling of both kidneys. With this scheme, a fraction of arterial blood in the aorta is inverted that will flow into the renal arteries. Since only those parts of the vasculature will exhibit high signal that are reached within TI by non-inverted blood, we propose to move the labeling edge closer to the vasculature of interest. In the context of renal non-CE MRA, different approaches are reported to deal with respiratory motion. These include the use of navigator MR signals to detect the position of the diaphragm [1-3] or the use of an external belt to monitor the respiratory motion [4-5]. The aim of this abstract is twofold: First, to compare the standard labeling approach with a single transverse inversion slab with a targeted scheme that uses multiple inversion slabs. Second, to compare a strategy that uses ECG-triggering, navigators and shorter TI values versus a respiratory triggered approach with longer TI.

METHODS: The described concepts were tested in eight healthy volunteers (5m/3f, age range 21y-68y, mean age 35y±18y) after obtaining informed consent. Experiments were carried out on a clinical MR system at 1.5T (MAGNETOM Avanto, Siemens Healthcare, Germany). The MR signal was acquired with the standard Body and Spine Tim Matrix coils of the system. An inversion-prepared, segmented b-SSFP sequence was used. Each acquisition was preceded by a fat sat module and ten dummy excitations with linearly increasing flip angle for signal catalyzation. Imaging parameters were: FOV=340mm x 240mm, matrix=304x200, 88 slices with a thickness of 0.9mm, flip angle = 90deg, TE/TR=1.5/3.5ms, BW=783Hz/Pix, GRAPPA=2. The segmentation was chosen to acquire a complete partition encoding in two shots, leading to a scheme with a total of 56 segments per shot. It was used for all scans to get a direct comparison, irrespective of expected scan time differences.

The standard labeling approach with a single transverse inversion slab was tested versus a targeted concept that uses two crossed oblique inversion slabs, positioned like a V to invert the hila of the kidneys, but not the aorta and the ostia of the renal arteries (Fig.1). For each labeling scheme, two different approaches were used to account for respiratory motion: An ECG-triggered protocol with navigator-based respiratory gating, and a protocol that was triggered to the breathing pattern with the help of a respiratory belt. In the ECG-triggered navigated approach, the data of shots where the diaphragm position did not fall into a self-adapting acceptance window of 4mm were discarded. The TI times were adapted to the cardiac cycle such that one shot was acquired with each heartbeat. This resulted in TI times ranging from 500ms to 750ms. In the respiratory triggered variant, a constant TI of 1200ms was chosen. For the long TI, additional inversion bands were placed inferior to the imaging volume in order to suppress venous inflow. In each of the resulting four datasets of each subject, the left and right renal artery tree were separately graded with a quality score between 0 and 4 (0: Ostium of renal arteries not assessable; 1: Ostium and proximal part of the main renal artery delineated; 2: Distal part of the main renal artery and first branch delineated; 3: Secondary branches delineated, 4: Third-order branches in the renal parenchyma delineated) and the mean result of the two sides was assigned to the dataset.

Fig.1: Standard labeling scheme with a single transverse inversion (left) and targeted approach with two oblique inversion slabs (right).

RESULTS: The average quality scores and scan times of the four different protocols are shown in tables 1 and 2, respectively. A higher score was found for the targeted V-shaped labeling scheme if compared to the corresponding transverse labeling approach. The score was also better for the respiratory triggered vs. the corresponding ECG-triggered protocol. With the used identical acquisition segmentation, the mean scan time of the scans with the respiratory belt was almost about a factor of three higher than that of the ECG-triggered acquisitions. While clinically diagnostic image quality was obtained with all protocols in the younger volunteers, best results were throughout achieved with the V-shaped labeling (examples in Fig.2). In two older subjects (55y, 68y), however, the depiction of the renal arteries was insufficient in the ECG-triggered protocol with transverse labeling. In these cases, distinct improvements were observed with both the targeted labeling and the respiratory triggered variant with longer TI.
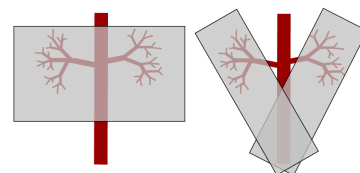
Score	Tra Label	V Label
ECG & Nav	2.0±1.1	3.0±1.2
Resp. Trigger	3.1±0.7	3.8±0.5

Table 1: Average scores

Scan time / min	Tra Label	V Label
ECG & Nav	3:14 ± 0:39	2:57 ± 0:33
Resp. Trigger	9:17 ± 2:08	8:53 ± 2:17

Table 2: Average scan times

Fig.2: Collection of best MIP results, all obtained with targeted V-shaped labeling.

DISCUSSION AND CONCLUSION: The results demonstrate that the use of a targeted labeling scheme helps to increase the amount of non-inverted blood that flows into the renal arteries, in particular into peripheral segments, and that background suppression around the aorta and ostia of the renal arteries is not required. Moreover, the use of longer TI values also showed to be beneficial in that there is more time available for blood to enter the vasculature of interest. In this study, an identical readout sequence (i.e. the same number of segments per shot or shot duration) was used throughout. Evidently, this led to unfavorably long acquisition times for the respiratory-triggered approach, but the rationale was to be able to directly assess the influence of the different protocol approaches and not to superimpose any other effects caused by different readouts (such as transient state effects or different fat sat efficiency). In conclusion, the use of a targeted labeling scheme and longer TI consistently helps to improve the image quality in IR-prepared b-SSFP non-CE MRA of the renal arteries. While - from a clinical perspective - the differences might not always be relevant for young subjects with high cardiac output, this approach should help to increase the robustness of the results in more problematic cases such as patients at higher age, with diminished flow conditions. Additional optimizations of the protocol, in particular with respect to robustness and decreased scan duration, and the clinical evaluation in patients will be the focus of further investigations.
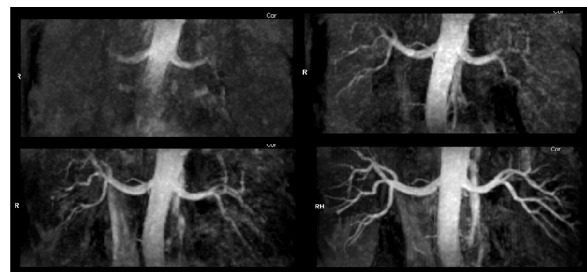

Fig.3: MIPs of a critical subject (f/ 55 y) with diminished flow conditions (top: TI=600ms & ECG & Nav; bottom: TI=1200ms & resp. trigger; left: transverse labeling; right V-shaped labeling)

REFERENCES: [1] Katoh et al., Kidney International 2004; 66:1272-1278. [2] Wyttenbach et al., Radiology 2007; 245:186-195. [3] Gandy et al., ISMRM 17 (2009), #405. [4] Yamashita et al., ISMRM 13 (2005), #1715. [5] Parienty, ISMRM 16 (2008), #918.