

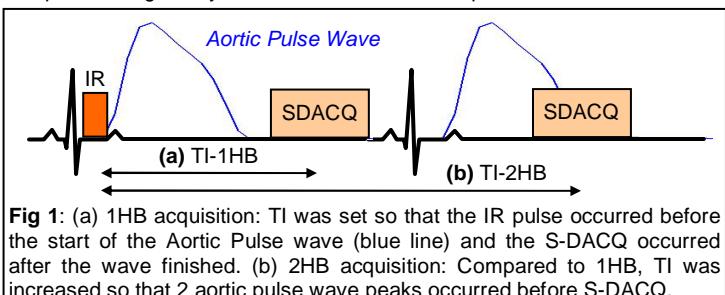
# Non-Contrast MR Angiography of the Renal Arteries: Improvements in Vessel Length and SNR with Multiple Heartbeat Inflow Period

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**Introduction:** In the past several years, rising concern about the risk of Nephrogenic Systemic Fibrosis has resulted in renewed interest in alternative non-contrast enhanced Magnetic Resonance Angiography (MRA) techniques, especially for the renal vasculature. However, one of the main limitations with current non-contrast studies is the poor visualization of the mid and distal renal vascular bed. Distal visualization is not only important for identifying distal stenosis but extremely vital for planning percutaneous procedures and screening for incidental aneurysms. Prior studies have focused on a slab-selective inversion recovery (sel-IR) steady-state-free-precession (SSFP) technique which depends on in-flowing blood to the imaging slab for signal in the arterial vasculature. In patients with slow flow in the renal arteries (either due to poor cardiac output or stenotic vessels), we have anecdotally noted that the length of the visible renal arteries is reduced for acquisitions using a single heart-beat. We hypothesized that increasing the inversion time (TI) to incorporate a second heart-beat (and thus another aortic pulse wave) could improve the length of renal artery visualized.

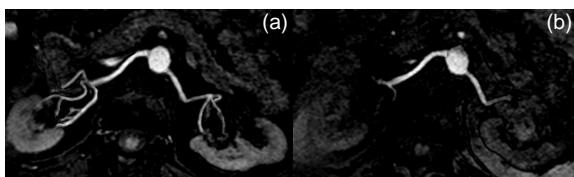
**Methods and Materials:** A sel-IR, navigator-gated, ECG-triggered, fat suppressed, segmented 3D SSFP sequence was used for non-contrast enhanced renal MRA acquisition on a 1.5T scanner (Magnetom Avanto, Siemens AG). Two different protocols were examined and are described in Figure 1. The 1-heartbeat (HB) acquisition typically had TI set to the max value such that the SSFP data acquisition (S-DACQ) would occur in diastole. The 2HB acquisition typically had TI set to 1.5 times the RR-interval, a balance between incorporating the second aortic pulse wave and suppressing background tissue signal. The following image parameters were common between the 2 protocols: TR/TE=3.72/1.86 ms; bandwidth=814 Hz/pixel; flip=90°; in-plane resolution=1.3x1.3 mm<sup>2</sup>; 40 partitions interpolated to 80; 80 mm slab thickness; parallel imaging acceleration (GRAPPA) = 2; NAV accept window=8 mm. In addition, a 2D phase-contrast sequence (TR/TE=7.8/3.8, flip=20°, NSA=2, VENC=120 cm/s) was run to assess aortic blood flow just superior to the renal artery origins. 20 patients (62±17 yrs, 12 females) with renal failure were imaged with both the 1HB and 2HB protocols as described above. Qualitative blinded review was done by 1 reviewer and scored as follows: 1=non-diagnostic; 2=adequate; 3=excellent. Significant differences were determined by a Wilcoxon signed rank test. Left (LRA) and right (RRA) renal artery lengths were measured using CoronaViz (Siemens AG) [2] and SNR/CNR measurements were made in the aorta and proximal RRA and LRA. Significant differences ( $p<0.05$ ) were determined with a paired student's t-test. Additionally, it was recorded whether S-DACQ occurred during peak velocity of the aortic pulse wave and if image artifacts/signal dropout occurred in the aorta and renal arteries (most likely due to SSFP's sensitivity to turbulent flow [3]). The velocity-time curves (VTC) from the phase-contrast data were plotted and compared to the start and end times of S-DACQ as shown in Figure 2. Vessel lengths in each category were then compared using 1-way ANOVA with a Bonferroni post-hoc test.



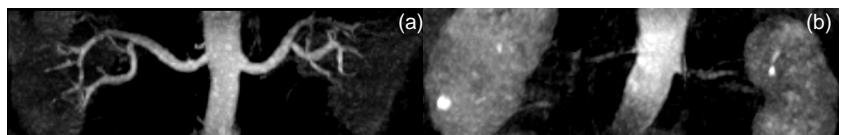
**Fig 1:** (a) 1HB acquisition: TI was set so that the IR pulse occurred before the start of the Aortic Pulse wave (blue line) and the S-DACQ occurred after the wave finished. (b) 2HB acquisition: Compared to 1HB, TI was increased so that 2 aortic pulse wave peaks occurred before S-DACQ.

**Fig 2:** The plots to the left show the VTC (blue line) from the aortic pulse wave and the position of S-DACQ (red rectangle). These plots were generated for all subjects and the percentage of overlap of the S-DACQ with VTC was calculated. Then, the results were binned into 4 categories:  $x=0$  (no overlap),  $0 < x < 0.5$ ,  $0.5 < x < 1.0$ , and  $x=1$  (complete overlap). (a) shows an example of the S-DACQ overlapping VTC at 100% ( $x=1$ ). (b) shows an example of <50% overlap ( $0 < x < 0.5$ ).

**Results:** Results of the comparison between 1HB and 2HB protocols are shown in Table 1 and Fig 3. Results of the analysis of S-DACQ overlap with VTC are shown in Figs 4 and 5.



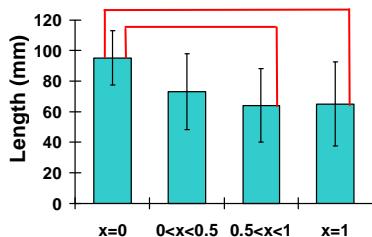
**Fig 3:** CoronaViz reconstructions of (a) 2HB acquisition and (b) 1HB acquisition in the same patient. Note the longer vessel length and presence of branches in the 2HB case.



**Fig 4:** MIP reconstructions of (a) 2HB acquisition with no overlap of S-DACQ and VTC and (b) 2HB acquisition with SDACQ completely overlapping VTC. (b) exhibits signal dropout in the aorta and the renal arteries most likely due to SSFP sensitivity to turbulent flow.

**Table 1:** Image Quality Analysis (QA), Length (L), SNR, and CNR comparisons between 1HB and 2HB acquisitions. \* indicates  $p<0.05$

Image QA	LRA-L (mm)	RRA-L (mm)	SNR Aorta	SNR LRA	SNR RRA	CNR LRA	CNR RRA	Scan Time (s)
1HB	2.3±0.8	46.8±24.5	61.8±28.5	93.0±47.1	91.8±46.6	84.2±39.8	60.6±32.0	53.2±27.9
2HB	<b>2.7±0.6*</b>	<b>60.2±27.1*</b>	<b>79.7±28.9*</b>	<b>112.6±57.3*</b>	<b>109.8±66.3*</b>	<b>104.4±57.8*</b>	64.6±46.5	57.7±39.9



**Fig 5:** Vessel lengths from the 2HB protocol related to percent overlap of S-DACQ with the VTC. ANOVA indicated a significant difference between all groups. Bonferroni significant differences between specific groups are shown with red lines.

**Conclusions:** Increasing TI in sel-IR SSFP to incorporate a second aortic pulse wave resulted in superior image quality, longer visualized lengths of renal vasculature, and increased SNR without significantly changing CNR. Only 1 case was non-diagnostic with the 2HB protocol while 4 were with the 1HB approach. To avoid SSFP-related flow artifacts, care must be taken to place the SDACQ outside the systolic period. Automated methods for selecting the optimal acquisition window could enable routine application of this 2HB method to improve non-contrast renal MRA.

**References:** [1] Katoh M et. al. MRM 53: 1228-33; 2005; [2] Aharon S et al. Proc. of ISMRM: 365; 2006; [3] Markl M et al. MRM: 50:892-903 ; 2003.  
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