Optimized Dark-Blood Imaging for Evaluation of the Aorta and Subclavian Arteries in Patients with Giant Cell Arteritis

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Purpose: Giant cell arteritis (GCA), also known as temporal arteritis or Horton's disease, is a granulomatous vasculitis of large- and medium-sized arteries[1]. The disease usually concerns the superficial cranial arteries with predominance of the temporal arteries[2]. However, GCA is not necessarily localized specifically to the temporal or cranial arteries. Involvement of extracranial arteries, mainly the aorta with its branches can also occur. Here, we present a novel high resolution multi-contrast MR protocol allowing the depiction of vascular geometry with large coverage including the aorta and the subclavian arteries.

Methods: MR-imaging: Ten patients (four male and six female, mean age 71.1±8.6) and twelve volunteers (eight male and four female, mean age 26.2±4.3) were imaged on a 3 T Magnetom Trio (Siemens Healthcare, Erlangen, Germany) MR imaging system. Signal acquisition was performed with a twelve-channel phased-array head coil, a two-channel neck coil and an eleven-channel coil (one flexible eight-channel phased-array on the patient chest in combination with three channels integrated in the patient table). Acquisition of aorta images was performed with electrocardiogram (ECG) triggering and respiratory navigation. In order to assess vessel wall thickness and potential edema T_2-weighted dark blood images of the aorta and subclavian arteries were acquired using a 3D SPACE sequence[3] (RARE sequence with Variable non-selective refocusing FLip angles V-FL). Contrast-enhanced magnetic resonance angiography (CE-MRA) examination was performed after intravenous gadolinium contrast agent administration (0.2 ml/kg body weight, injection rate 3ml/sec). A full-resolution pre-contrast data set was acquired for background signal elimination through mask subtraction followed by maximum intensity projection. Subsequently, T_1-weighted images of four stations (head, neck, thorax and abdomen) where acquired using a 3D GRE (Volumetric Interpolated Breath-hold Examination - VIBE) sequence with fat saturation. Mural inflammatory signal enhancement can be identified using T_1-weighted images. Superficial cranial vessel wall imaging was performed using a 2D multi-slice spin-echo with high in-plane sub-millimeter spatial resolution (0.2×0.2×3mm^3). Dark-blood aorta images were acquired with a 2D Turbo FLASH sequence with 20 segments/cardiac cycle. The repetition time of the double inversion recovery (DIR) dark-blood preparation pulse was TR = 2×R-R intervals. In order to account for the shorter T_1 of blood after contrast agent administration the time delay between the non-selective inversion pulse and data acquisition was customized for each patient using a TI scout sequence. T_1-weighted dark-blood images of the subclavian arteries were acquired using a 3D SPACE sequence. The 3D SPACE sequence was used because it has inherent dark-blood capabilities. In order to maximize the dark-blood effect, the readout direction was set in the superior-inferior direction for the aorta examination and in the left-right direction for the subclavian arteries.

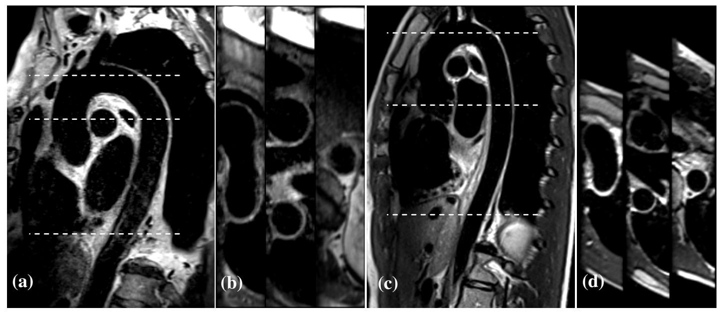

Figure 1: Multi-planar reconstruction of T_2-wighted aorta images of an 81-year-old female patient (**a**) sagittal-oblique and (**b**) transverse orientation and of a 25-year-old female healthy volunteer **(c)** sagittal-oblique and **(d)** transverse orientation

	Method (RARE- or turbo-factor)	TE/TR [ms]	Flip angle	FOV [mm] (read/phase)	Matrix (read/phase)	Slices/ Partitions	Spatial res.[mm]	Acquisition time
Aorta	3D SPACE	104/AvRC	90°/V-FL	260 × 243	256 × 252	36	1.0×1.0×1.0	8:17 ± 1:48
Subclavian arteries	3D SPACE (87)	106/2500	90°/V-FL	260 × 164	256 × 174	56	1.0×1.0×1.0	7:19
Aorta	2D Turbo-Flash (22)	4.8/10.8	30°	255 × 214	208 × 174	8-10	1.2×1.2×3	< 45 sec/slice
Subclavian arteries	3D SPACE (37)	20/1060	90°/V-FL	260 × 176	256 × 185	56	1.0×1.0×1.0	7:47

Table 1: Pulse sequence parameters for MR-methods used for dark blood multi-contrast aorta and subclavian arteries examination *Average respiratory cycle

Results: Dark-blood T_2-weighted aorta examinations were successfully completed in all patients (Fig. 1**a**,**b**) and volunteers (Fig. 1**c**,**d**). High image quality with 1.0 mm^3 isotropic resolution allowed for clear delineation of the boundary separating the lumen from the vascular wall. For the patient study, blood signal suppression was less effective in post contrast agent administration T_1-weighted examinations of the aorta (Fig. 2**a**) in comparison to the volunteer study (Fig. 2**b**). However, the obtained contrast (Fig. 2**a**) enables clear differentiation between the aortic wall and blood. Incomplete blood suppression in post-contrast agent administration T_1-weighted examinations can be explained by a suboptimal sagittal oblique orientation of the acquired slices with respect to the blood flow. Dark-blood subclavian arteries multi-contrast examinations were successfully completed in three volunteers (Fig. 3). Both T_2- and T_1-weighted examinations depict complete suppression of luminal signal due to the intrinsic dark-blood capabilities of 3D SPACE.

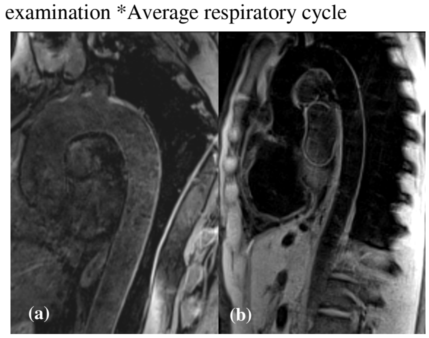

Figure 2: **(a)** Representative T_1-weighted post contrast aorta image of a 63-year-old male patient **(b)** Representative T_1-weighted of the same 25-year-old female healthy volunteer

Discussion: This preliminary study showed the effectiveness of 3D SPACE and 2D Turbo-FLASH with DIR preparation for dark-blood examination of aorta and subclavian arteries. T_2-weighted examinations of aorta and subclavian arteries depicted excellent blood signal suppression. Dark-blood T_1-weighted investigations were successfully completed in volunteers for both aorta and subclavian arteries. Considering the dark-blood capabilities of 3D SPACE, further work includes the modification of the pulse sequence for post-contrast agent administration T_1-weighted examinations of the aorta. ECG triggering and respiratory navigation necessary for an aortic examination do not allow the obtainment of a sufficiently short repetition time. The current implementation of 3D SPACE with the 2D navigator for respiratory motion detection allows obtaining a repetition time equal to the average respiratory cycle (AvRC). With such a long TR, T_1 contrast can be achieved only by using an inversion recovery (IR) preparation. Our initial examinations of four volunteers showed a high variability of image quality acquired with IR 3D – SPACE (data not shown). T_1 contrast could also be achieved with continuous ECG triggering (TR = 1 R-R interval) and acceptance/rejection of acquired data based on respiratory navigator position.

Conclusion: The presented protocol provides a robust and efficient dark-blood aortic and subclavian arteries wall imaging routine and is implemented in our clinical trials for integrated head-thoracic vascular MRI for the assessment of GCA.

References: [1] Salvarani C *et al.*, N Engl J Med 2002; 347(4):261-271. [2] Bley TA *et al.*, MAGMA 2005; 18:193-200. [3] Mugler et al., Radiology 2000; 216:891-899.

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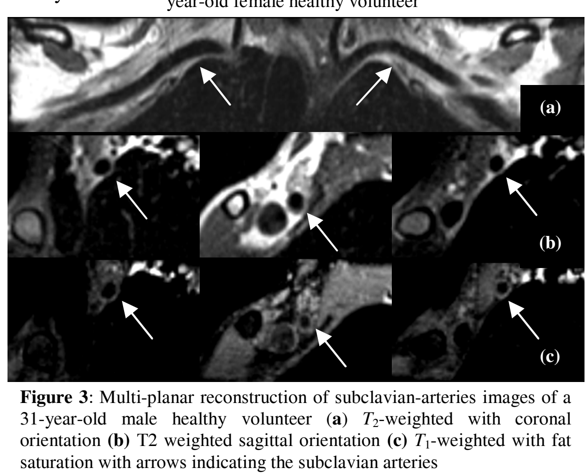

Figure 3: Multi-planar reconstruction of subclavian-arteries images of a 31-year-old male healthy volunteer (**a**) T_2-weighted with coronal orientation **(b)** T2 weighted sagittal orientation **(c)** T_1-weighted with fat saturation with arrows indicating the subclavian arteries