Comparison between ungated multi-slice and gated single-slice double inversion recovery prepared black-blood fast spin echo sequences applied at 3T

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Introduction

Multi-contrast high-resolution MRI has been widely used as a method for assessing carotid plaque tissue subtypes [1]. However, its application is still mainly in the research domain. One of the major issues is the long acquisition times required to obtain the multiple contrast weightings at multiple slice locations. Many protocols to-date have used ECG-gated, double inversion recovery (DIR) prepared, fast spin echo (FSE) single-slice acquisition strategies to obtain black blood images with the following contrast weightings: T_1-weighted (T_1W), T_2-weighted (T_2W) and proton density weighted (PDW). Issues with this approach are that the image acquisition time and, to some extent, the relative contrast obtained is dependent on the subject's heart rate. In practice, many patients with carotid atheroma are treated with beta-blockers making them bradycardic, which prolongs the length of the overall acquisition time. A multi-slice ungated DIR prepared FSE sequence has previously been proposed [2]. The objectives of this study were two fold: 1) to perform a side-by-side comparison of the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) by applying the single-slice gated and multi-slice ungated strategies; and 2) to quantify the repeatability of the contrast. The sequences were applied to a normal cohort and to an atherosclerotic patient cohort at 3T.

Methods

Ten healthy volunteers (4/10 male, age: 38 ±11.6) and 3 patients with known carotid atheroma (2/3 male, age: mean 79 ±7.7, max stenosis 30-49%) were imaged, using a bilateral 4-channel phased-array carotid coil (Flick Engineering Solutions, Winterswijk, The Netherlands) on a 3T whole body MR system (Signa HDx, GE Healthcare, Waukesha, WI). A 2D time-of-flight sequence was performed to identify the diseased arterial segment. T_1W, T_2W and PDW DIR prepared, fat suppressed, FSE images were initially acquired using the standard ECG-gated sequences in a single slice strategy. Then using the ungated sequence, T_2W and PDW images were acquired using a multi-slice strategy (four slices per TR), while the T_1W ungated images were acquired using a single slice acquisition strategy, i.e. one slice per TR [3]. The slice thickness, FOV and matrix-size were consistently set to 2mm, 10x10cm and 256x256. The rest of the imaging parameters are reported in Table 1. In the normal volunteer cohort 4 slices were prescribed at the location of the carotid bifurcation, and in the patient cohort T_1W scout images were initially performed to encompass the entire diseased segment of artery and then 4 slices containing the largest plaque were selected. All sequences were performed twice to obtain replicates 1&2. Separate noise-only images were acquired to encompass matched slice locations using a gradient echo sequence where the excitation pulse was disabled. The images were imported into the VesselMass software (Leiden University Medical Centre, Lieden, The Netherlands). Regions of interest were defined to demarcate the outer wall and lumen boundaries. In the volunteer cohort one side (left or right) was selected at random. In the patient cohort the diseased arteries were selected. SNR of the vessel wall ($SNR_{volunteers}$) and CNR of the vessel wall/lumen ($CNR_{volunteers}$) were computed in the volunteers and in the patients plaque tissue instead of vessel wall was select giving SNR_{plaque} and CNR_{plaque}.

Results

The side-by-side comparisons of SNR and CNR for the two methods in the normal and patient cohort are shown in Figure 1. The reductions of SNR and CNR with ungated sequences with respect to the gated sequence are summarized in Table 2. These results show the overall expected reduction in SNR and CNR due to the reduced acquisition time. However the overall spread of the distribution is substantially reduced for the ungated sequence. The mean CNR difference is smaller than the mean SNR difference between gated and ungated acquisitions due to an observed improvement in luminal suppression with the ungated sequence at 3T. The repeatability of the SNR and CNR measurements are shown in Table 3. These results suggest that overall the gated sequences produce less consistent contrast, most likely as a result of variations in heart rate.

Discussion

Overall the ungated sequence produced more consistent contrast between subjects and within subjects as well as providing an overall reduction in the acquisition time. It is expected that this improvement in repeatability will be important for subjective interpretation of plaque characteristics and for the use of automated tissue classification algorithms.

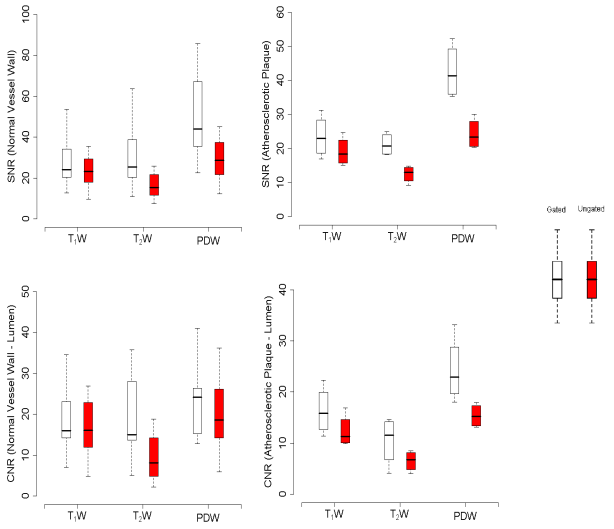

Figure 1

Table 1 Pulse sequence parameters listed as (ungated/gated) where different

	T_1W	T_2W	PDW	Noise Image
TR (ms)	800 / 1 R-R	2500 / 2 R-R	2500 / 2 R-R	20
TE (ms)	13.3	11.2	50.0	5.7
NEX	3	3	3	1
RBW	20.83	31.25	31.25	31.25
ETL	10	12	12	1
Scan Time (s)	65/80†	42.5/136†	42.5/136†	10

scan time is quote per slice, †based on a heart rate of 60bpm

Table 2 Ratio of reduction in SNR and CNR [ungated/gated]

	T_1W	T_2W	PDW
$SNR_{volunteers}$	0.77 [0.73-1.03]	0.59 [0.51-0.65]	0.62 [0.55-0.69]
$CNR_{volunteers}$	0.81 [0.73-1.00]	0.48 [0.38-0.53]	0.77 [0.62-1.06]
SNR_{plaque}	0.94 [0.89-1.00]	0.60 [0.57-0.62]	0.57 [0.55-0.60]
CNR_{plaque}	0.81 [0.51-0.81]	0.57 [0.51-0.81]	0.65 [0.53-0.78]

median [inter-quartile range]

Table 3 Standard deviations of differences between replicate 1 & 2

	T_1W		T_2W		PDW	
	Ungated	Gated	Ungated	Gated	Ungated	Gated
$SNR_{volunteers}$	2.04	6.86	2.20	4.50	2.54	4.52
$CNR_{volunteers}$	1.90	3.14	3.36	3.50	3.65	5.19
SNR_{plaque}	1.23	0.81	0.64	0.42	1.07	1.63
CNR_{plaque}	1.29	1.43	0.60	1.00	2.46	7.19

References [1] Yuan C, et al. NMR in Biomedicine, 2006. 19:636-54 [2] Yarnykh VL, et al. J Magn Reson Imaging, 2003. 17(4): 478-83 [3] Yarnykh VL, et al. J Magn Reson Imaging, 2006. 23(5):691-98