Improved Cardiac 1H-MR Spectroscopy at 3 T using High Permittivity Materials

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Target audience: Cardiologists and radiologist interested in cardiac energy metabolism and researchers and RF engineers interested in RF shimming at using high permittivity materials.

Purpose: Myocardial triglyceride content (MTGC) reflects the process of ectopic intracellular fat accumulation, which is linked to the development of heart failure (1). Quantification of MTGC using cardiac proton magnetic resonance spectroscopy (cardiac 1H-MRS) has proven to be important in the field of cardiovascular disease related to obesity, metabolic syndrome and diabetes mellitus type 2 (DM2) (2-5). However, cardiac 1H-MRS is challenging due to an intrinsic low signal-to-noise ratio (SNR), static magnetic field (B0) inhomogeneities, dynamic B0 fluctuations, and dynamic transmit field (B1+) inhomogeneity. Recent work has shown that it is possible to increase the quality of 3T cardiac imaging, while simultaneously increasing B1+ homogeneity and decreasing the required power, using high permittivity "dielectric" pads (HP pads) (6). Therefore, the purpose of this study was to determine whether the application of HP pads can be used to increase SNR in cardiac 1H-MRS, potentially allowing shorter data acquisition times.

Methods: The institutional review board approved the study protocol, and written informed consent was obtained from all participants. Scans were performed on a 3T Philips Ingenia whole body MRI scanner (Philips Healthcare, Best, Netherlands). In twenty healthy volunteers water-suppressed point resolved spectroscopy (48 averages) spectra were acquired in the interventricular septum (Fig 1) without and with the HP pads. The signal to noise ratio (SNR) and myocardial triglyceride content (MTGC) were measured without and with the HP pads, and the results were compared with a paired samples Student's t-test. In post-processing averages were reduced from 48 to 36, 24 and 12 averages, corresponding to acquisition times of 4min 55s, 3min 41s, 2min 27s and 1min 14s respectively. The SNR was then calculated for these averages. To show clinical feasibility, cardiac proton MR spectroscopy using the HP pads was performed in a diabetes mellitus type 2 (DM2) patient.

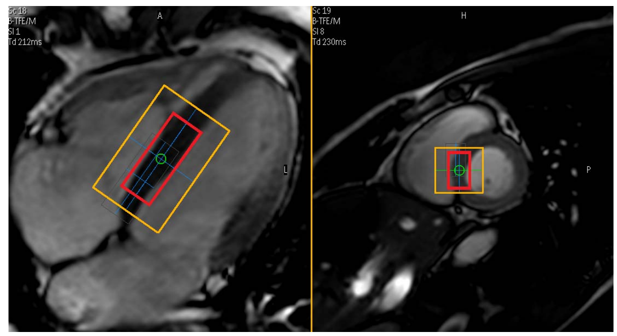

Figure 1. Placement of the VOI (red box) in four chamber (left) and short axis view (right) at 25% of the RR-interval. The (outer) shim box is shown in orange.

Results: Application of the HP pads increased SNR from (mean±SD) 27.9±15.6 to 42.3±24.4 ($p<0.0001$), resulting in a mean gain factor of 1.6±0.51 which can be used to decrease the number of averages by a factor of 2.6±1.1. The average acquisition time was thereby reduced from 4min 55s to 1min 57s. Spectra of three different volunteers with a wide range of BMI's are shown in Figure 2. An clear improvement in SNR is visible in the spectra acquired with the HP pads. In Figure 3, the SNR of the MTGC signal as a function of the acquisition time is shown. It can be seen that significant reductions in time can be achieved by applying the HP pads for the same SNR value as the scans without pads. The MTGC was 0.39%±0.17 without pads and 0.38%±0.15 with pads ($p=0.83$) for the healthy volunteers. The MTGC in the DM2 patient was 1.29%.

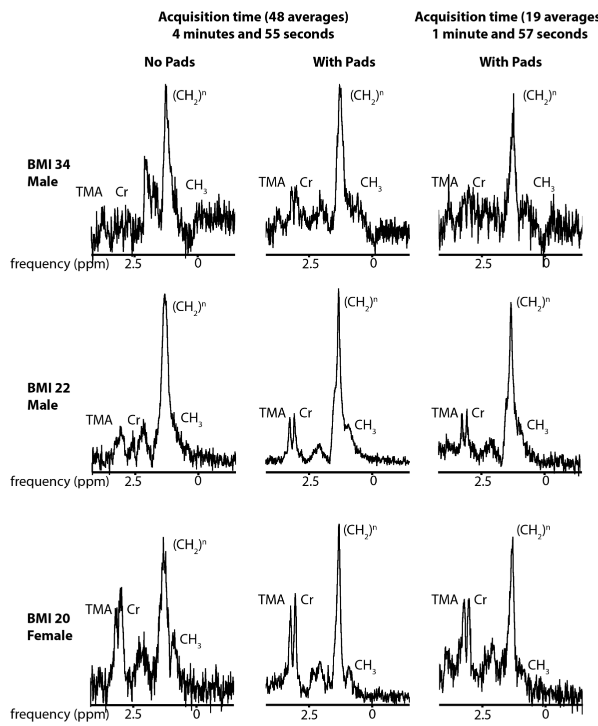

Figure 2. Water suppressed spectra of three volunteers, two male and one female, with different BMI values. The spectra on the left were acquired without the HP pads and the spectra in the centre and the right are with the HP pads. The spectra shown on the right are the same as the middle spectra but have been reconstructed with only the first 19 averages of the total 48 averages. In practice this will result in a reduction in acquisition time by a factor of 2.6 effectively going from 4 minutes and 55 seconds to 1 minute and 57 seconds.

Discussion and Conclusion: The main finding of this study is that the HP pads significantly increase the SNR of cardiac 1H-MRS at 3T, reducing the acquisition time by a factor of 2.5, without compromising spectral quality. Although volunteers noted the extra weight of the HP pad in addition to that of the receive array on their chest, they did not rate this as uncomfortable. Despite the clear increase in SNR afforded by the use of the HP pads, it is important that their use does not introduce a measurement bias into MTGC quantification. Our results showed statistically identical values without (0.39%±0.17) and with (0.38%±0.15) the HP pads ($p=0.83$) meaning the lipid quantity is not affected by using the HP pads. The MTGC for the healthy volunteers was in agreement with previous studies (7-9) while the MTGC in the DM2 patient was much higher (1.29%) than healthy volunteers.

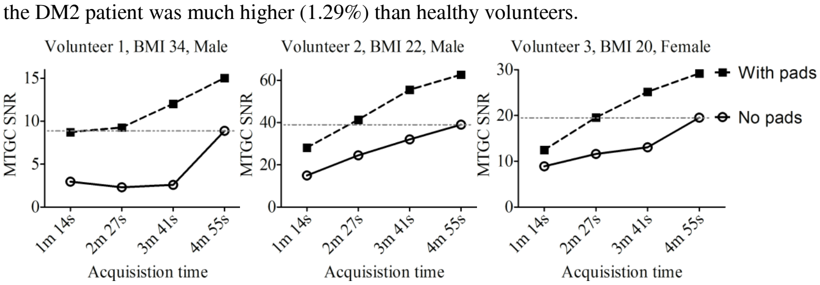

Figure 3; SNR of the MTGC signal acquired in the same volunteers as shown in figure 2 without and with the HP pads. On the x-axis the acquisition time of the water-suppressed spectra is shown. The horizontal dotted line gives the SNR of the total acquisition (48 averages) without the HP pads.

References: [1] Bizino MB et al, Heart 2014 Jun;100(11):881-90 [2] Kankaanpaa M et al, J.Clin.Endocrinol.Metab 2006 Nov;91(11):4689-95 [3] McGavock JM et al, Circulation 2007 Sep 4;116(10):1170-5 [4] Reingold JS et al, J.Am.Coll.Cardiol. 2003 Nov 5;42(9):1587-93. [5] Szczepaniak LS et al, Magn Reson.Med. 2003 Mar;49(3):417-23. [6] Brink WM, Webb AG, Magn Reson.Med. 2014 Apr;71(4):1632-40. [7] Weiss K, Martini N, Boesiger P, Kozerke S, NMR Biomed. 2013 Mar;26(3):276-84. [8] Rial B et al, Magn Reson.Med. 2011 Sep;66(3):619-24. [9] Faller KM et al, Heart Fail.Rev. 2013 Sep;18(5):657-68.