Measuring the unsaturation index in red and yellow bone marrow using ^{1}H MR spectroscopy

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Target audience: General audience and those dealing with metabolism and MR spectroscopy.

Purpose: Significant portions of bone cavity are occupied by fat. Two different kinds of bone marrow are distinguished: Red bone marrow (RBM) composed of 40% fat, 40% water and 20% proteins and yellow bone marrow (YBM) composed of 80% fat, 15% water and 5% proteins. Yellow bone marrow expands during aging and in conditions which affect energy metabolism, indicating that fat in bone is under similar regulatory mechanisms as other fat depots (1).

Up to now mainly intersubject changes in spinal red bone marrow were investigated (e.g. in osteoporosis or osteoarthrosis) (2). Pansini et al. (3) studied the influence of age and sex on the fat content of bone marrow in different regions of the femur. They found a significant correlation between age and fat content, as well as a difference between male and female in a subgroup aged 20 to 30 years. Only one previous study tried to compare lipid unsaturation in red and yellow bone marrow within the same bone (femur) but the line width of the peaks were broadened due to the trabecular bone structure in the femur head (4) and therefore the small peak of the olefinic fat compound could not be quantified.

In this study we measured the unsaturation of red and yellow bone marrow fat using a long TE sequence to remove the water signal overlapping with the olefinic resonance. We also correlated these parameters to physical activity and age.

Methods: 9 female volunteers [mean age: 27.9 ± 7.9 years; mean body mass index (BMI): 22.3 ± 1.9 kg/m²] who consented to the protocol approved by a local ethics board were studied on a clinical scanner (3T Philips Achieva, Best, The Netherlands). ^{1}H spectra were acquired using a SENSE XL Torso coil (Philips Healthcare, Best, The Netherlands). Prior to acquisition, a 2×0.7×0.7 cm³ voxel of interest was placed within the bone marrow of the diaphysis in the right femur. 3D localized spectra [TR = 4 s, TE = 200 ms, NSA = 64] were obtained using PRESS as described previously (5). Red and yellow bone marrow were distinguished by measuring the fat content using a short TE sequence (TR = 4 s, TE = 35ms, NSA = 32). Post-processing was done using NUTS (Acorn NMR, Livermore, CA). Physical activity was measured using the BAECKE questionnaire (6). The unsaturation index was calculated as the area under the olefinic peak divided by the area under the CH_2 and CH_3 peak. The fat fractions were calculated as $(CH_2 + CH_3)/(CH_2 + CH_3 + H_2O)$. Fat fractions below 75% were assigned to red bone marrow and fat fractions above 90% were assigned to yellow bone marrow.

Results: It is feasible to measure the fat content and unsaturation index of red bone marrow, although the SNR (mean SNR = 10.1 ± 4.8) of red bone marrow spectra was smaller and the linewidth (mean linewidth = 22.8 ± 3.8 Hz) was larger compared to spectra from YBM (mean SNR = 28.0 ± 11.7, mean linewidth = 18.5 ± 3.4 Hz). In two subjects (age > 30 yrs) no red bone marrow was found (fat fraction > 75%). The mean fat fraction of RBM was 63.2 ± 9.4%, the mean fat fraction of YBM was 97.5 ± 3.3%. The individual minimum fat fraction of the bone marrow correlated with age (p = .03, R = 0.70). RBM unsaturation was lower than YBM unsaturation (6.61 ± 1.36% vs. 8.30 ± 1.42%, p = 0.04, N = 7). The BAECKE sport index correlated with RBM unsaturation (p = 0.05, R = 0.75, N = 7).

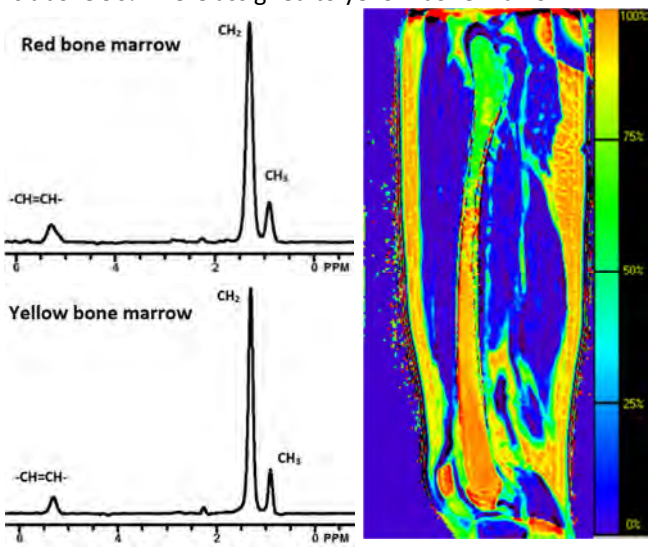

Fig. 1 Spectrum of a) red and b) yellow bone marrow in the femur c) mDixon image for visualization of red and yellow bone marrow distribution

Discussion: Consistently with the conversion from RBM to YBM during aging we observed a correlation between RBM fat fraction and age. The lower unsaturation index of RBM compared to YBM may be related to the higher metabolic turnover in red bone marrow. Physical activity seems to influence the RBM fat metabolism probably connected to either an increased need of red blood cells or mechanic reasons.

Conclusion: For the first time intrasubject changes in bone marrow fat unsaturation between yellow and red marrow have been shown. Further studies in obese subjects and subjects with a larger age range are needed to show whether other metabolic parameters influence the composition and amount of red and yellow bone marrow.

References: 1. Krings A, et al. Bone 2012;50:546–552. 2. Yeung DKW, et al. J. Magn. Reson. Imaging 2005;22:279–285. 3. Pansini V, et al. J. Magn. Reson. Imaging JMRI 2014;39:369–376. 4. Machann J, et al. Eur. J. Radiol. 2008;67:275–284. 5. Lundbom J, et al. NMR Biomed. 2011;24:238–245. 6. Baecke JA, et al. Am. J. Clin. Nutr. 1982;36:936–942.