Proton Magnetic Resonance Spectroscopy for Assessment of Human Body Composition

Masayuki KAMBA1, Wei CHEN2, Koji KIMURA1, Masahiko KODA4, Toshihide OGAWA5

1Center for Magnetic Resonance Research, University of Minnesota, 2021 6th Street, S.E., Minneapolis, Minnesota USA; 2University of Minnesota, CMRR, Minneapolis, MN; 3Department of Biochemistry, Tottori University Faculty of Medicine, Nishi-machi, Yonago, Japan; 4Department of Clinical Laboratory Medicine, Tottori University Faculty of Medicine, Nishi-machi, Yonago, Japan; 5Department of Radiology, Tottori University Faculty of Medicine, Nishi-machi, Yonago, Japan;

Introduction
Although estimates of human body composition are made using a wide variety of techniques (1), there is no technique optimal for all clinical circumstances. There is a need for a body composition measurement technique which is rapid, safe, sufficiently accurate, and feasible for clinical practice. We have proposed a proton magnetic resonance spectroscopy (MRS)-based technique for measurement of human body composition (2). In this study, we compared our MRS-based technique with the total body water technique, in order to determine the accuracy and usefulness of the former for assessment of human body composition.

Methods
Sixteen volunteers (seven men and nine women) were enrolled as participants. Their mean age was 43.2 ± 13.7 (SD) years. The body mass index of the participants ranged from 20.2 to 37.6 (27.7 ± 4.2 (mean ± SD)).

MRS examinations were performed with a Magnetom Vision (Siemens, Erlangen, Germany) operating at 1.5 T using an embedded body coil. We used liquid fluorocarbon pads (Sat Pad; Alliance Pharmaceutical, San Diego, CA, USA) and multi-angle projection shim to improve static magnetic field homogeneity. Non-localized proton MR spectra were acquired from the human body using single free induction decay (FID) with a flip angle of 90°, and 512 data points at a spectral width of 1 kHz. Five FIDs were obtained at 1 min intervals. MR spectra were obtained at three different positions: the chest to abdomen, the abdomen to pelvis, and the pelvis to thigh regions. We placed a bottle of benzene (2,200 g) at the level of the magnet isocenter under the subject, and used it as an external reference. This procedure required approximately 50 min.

The raw data were zero-filled to 1024 points. After fast Fourier transformation, spectral data were obtained through manual phase and baseline correction. Peak areas for water protons, methyl and methylene protons, and benzene protons were calculated by fitting the spectrum to a sum of Lorenzian curves. The MRS metabolite ratio was defined as the ratio of fat methyl and methylene proton resonance to water proton resonance. The peak areas for the chest to abdomen and the pelvis to thigh regions were normalized to the benzene proton resonance, and a weighted average of the MRS metabolite ratios for the two positions was calculated from the five FIDs for each position.

Total body water was determined by the deuterium oxide dilution method. Body fat was calculated assuming 73.2% of lean body mass to be water.

Analysis of covariance and linear regression analysis were used for statistical analyses.

Results
Figure shows a representative spectrum from the human body. Resonances of protons of water, fat methyl and methylene, and benzene were resolved.

There were significant linear relationships between the ratio of fat to lean body mass estimated by total body water and the MRS metabolite ratios for the chest to abdomen (r = 0.859), the abdomen to pelvis (r = 0.918), and the pelvis to thigh regions (r = 0.649), and the weighted average of the MRS metabolite ratios for the chest to abdomen and the pelvis to thigh regions (r = 0.822). Homogeneity of slopes and means was not rejected by analysis of covariance (P = 0.867 and P = 0.319, respectively). However, homogeneity of residual variances was rejected (P = 0.002).

Two models were selected for prediction of the ratio of body fat to lean body mass by multivariate regression analyses. The regression equations were as follows:

Fat/lean body mass = 1.083 x MRabdomen to pelvis - 0.101, (2)
R = 0.918, adjusted R² = 0.832, P = 5.16 x 10⁻⁷.

Discussion and Conclusions
Our MRS-based technique enabled assessment of fat content relative to that of water. There was a linear relationship between the ratio of the fat methyl and methylene proton resonance to the water proton resonance and the ratio of body fat to lean body mass. This MRS metabolite ratio can be used as an indicator of human body composition.

The best prediction of the ratio of body fat to lean body mass was obtained by combined use of the MRS metabolite ratio for the abdomen to pelvis region and that for the pelvis to thigh region (eq. 1). A negative correlation between the MRS metabolite ratios for these two positions in this equation appears compatible with the previous findings of adipose tissue distribution (3,4). The best single predictor of the ratio of body fat to lean body mass was the MRS metabolite ratio for the abdomen to pelvis region (eq. 2). The MRS metabolite ratio for the abdomen to pelvis region is the most useful and sufficiently accurate in predicting total body composition.

Our MRS-based technique enabled assessment of body fat in combination with water. It is relatively rapid, safe, sufficiently accurate, and feasible for use in clinical practice.

References