MR Measurement of Visceral Fat: Assessment of Metabolic Syndrome

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One diagnostic criterion for metabolic syndrome is obesity from the accumulation of visceral fat; others include abdominal circumference and area of visceral fat as measured by computed tomography (CT) at the umbilical level. We evaluated visceral fat using frequency-selective excitation magnetic resonance (MR) imaging SPAIR (spectral attenuation with inversion recovery) water suppression THRIVE (3D T1-high resolution isotropic volume examination). Fifty of 70 slices with 2-mm interval were used to render and measure volume of visceral fat ranging within 10 cm of the umbilicus; the area of visceral fat at the umbilical level was also measured. Imaging was completed using breath hold within 14 s. Image processing was easier than using CT.

Keywords: metabolic syndrome, visceral fat, MRI, CT, water suppression THRIVE

Background

At the annual meeting of the Japanese Society of Internal Medicine in April 2005, the diagnostic criteria for metabolic syndrome—hypertension, hyperglycemia, hyperlipidemia, and obesity—were presented within the context of the prevention of lifestyle-related diseases. According to the criteria, 85 cm for men and 90 cm for women are the standards for abdominal circumference measured at the umbilical level, and particular focus is placed on visceral fat. However, subcutaneous and visceral fat cannot be differentially evaluated by measuring abdominal circumference; therefore, a criterion was set for measuring the area of visceral fat at the umbilical level (100 cm2). However, computed tomography (CT) cannot frequently be used because of its associated risk of radiation exposure.

Study Objective and Subjects

In a volunteer from whom written consent was obtained, magnetic resonance (MR) imaging was used for planimetric evaluation of visceral fat at the umbilical level, processing of 3D images, and volumetric evaluation of visceral fat in a cephalocaudal range of 10 cm centered on the umbilicus. The data were compared to those obtained by CT in the same subject.

Methods

CT: Toshiba Asteon Multi (4DAS) 120 keV 230 mA (thickness, 4 mm; interval, 2 mm); MR imaging: Philips Intra Achieva Nova Dual 1.5T SENSE body coil (4-ch) THRIVE (thickness, 2 mm; over-contiguous slices); SPAIR water suppression (delay time, 90 ms; echo time [TE], 1.9 ms; repetition time [TR], 3.9 ms); flip angle: 5°; 70 slices; scan time: 14 s (breath hold). Images were processed using 50 slices (scanned in the range of 10 cm centered on the umbilicus) and excluded 10 slices each of the upper and lower regions to avoid heterogeneity in fat intensity caused by phase return in the slicing direction in 3D. After setting a visual threshold for exclusive mask display of fat, 3D volume rendering was carried out, and visceral fat volume was displayed after adjusting opacity and deleting...
Fig. 1. Spectral attenuation with inversion recovery (SPAIR) water suppression 3D $T_1$-high resolution isotropic volume examination (THRIVE; 4-mm slice thickness and 2-mm interval)

**a:** subcutaneous fat plus visceral fat
- i: region of mask display of the original image of fat obtained at the umbilical level (shown in green), $316 \text{ cm}^2$
- ii: VR image and volume in the range of 10 cm centered at the umbilicus, $2863 \text{ cm}^3$

**b:** visceral fat
- i: region of exclusive mask display of visceral fat obtained at the umbilical level (shown in green), $84 \text{ cm}^2$
- ii: VR image and volume of visceral fat in the range of 10 cm centered on the umbilicus, $718 \text{ cm}^3$

Results

The SPAIR water suppression technique accentuated the high intensity of fat. Intestinal contents were contoured at low intensity, and exclusive mask display of fat as well as 3D imaging, planimetric, and volumetric evaluations could easily be performed (Fig. 1). Area and volume of visceral fat measured by CT were slightly larger than with MR imaging (Fig. 2).

Discussion

CT data for the area of visceral fat measured at the umbilical level also varied depending on intestinal motility, in particular, with regard to the presence or absence of the transverse colon at a position at the same height as the umbilicus. To measure visceral fat by CT, it is sometimes enclosed manually or differentiated by threshold CT value (lower limit: between $-160$ and $-150$ HU; upper limit: between $-50$ and $-40$ HU). However, because of the partial volume effect of air in many cases of differentiation by threshold, the CT value of intestinal contents present concomitantly with air falls within the threshold range and approximates that of fat; it is therefore necessary to exclude the region manually. Accordingly, CT measurement of the volume of visceral fat is believed to be difficult and is thus avoided. However, using MR imaging, we conducted planimetric evaluation of visceral fat at the umbilical level, processing of 3D images, and volu-
Fig. 2. Computed tomography (CT; 4-mm slice thickness and 2-mm interval)

**a:** subcutaneous fat plus visceral fat

1. Region of mask display of the original image of fat obtained at the umbilical level (shown in green); CT has difficulty in realizing the exclusive 3D display of fat as well as differentiation between colonic contents and visceral fat; 327 cm$^2$

2. Both subcutaneous and visceral fats exhibit a low density in the VR image in the range of 10 cm centered on the umbilicus, 3005 cm$^3$

**b:** visceral fat

1. Region of exclusive mask display of visceral fat obtained at the umbilical level (shown in green); CT has difficulty in realizing the exclusive 3D display of fat as well as differentiation between colonic contents and visceral fat; 94 cm$^2$

2. VR image and volume of visceral fat in the range of 10 cm centered on the umbilicus, 765 cm$^3$

Metric evaluation of visceral fat in a cephalocaudal range of 10 cm centered at the umbilicus.

SPAIR water suppression THRIVE accentuates high-density fat and readily allows 3D display of fat, providing a good contrast to other organs. Although fat marrow in the spine is a problem using this technique, it is easy to differentiate because it is separated from intra-abdominal visceral fat by the thick iliopsoas muscle.

With the SPAIR water suppression THRIVE technique, water can be selectively inverted, and when the $T_1$-relaxation of the water signal reaches the null point, only the fat signal is excited by impression of the excitation pulse.

In the present study, distortions in MR images acquired at the same time as CT were not problematic. It was felt errors caused by intestinal motility might have been reduced more in volumetric than in planimetric evaluation.

Prevention of lifestyle-related diseases also require self-review, and so, it is felt that the visually appealing volumetric evaluation by 3D display of visceral fat may facilitate such self assessment. Although interviews to exclude subjects having contraindications for undergoing MR imaging, such as those having cardiac pacemakers, and wearing a coil require considerable time, scanning time is actually short, at 14 s, and results in good throughput.
Conclusion

3D display and volumetric examination of visceral fat using SPAIR water suppression THRIVE were easily performed and we believe more useful than conventional planimetric examination by CT, which carries the risk of exposure to radiation.

References