TECHNICAL NOTE

Measuring Visceral Fat with Water-Selective Suppression Methods (SPIR, SPAIR) in Patients with Metabolic Syndrome

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We attempted to measure the area and volume of visceral fat using magnetic resonance (MR) imaging to avoid radiation exposure. We used water suppression-spectral attenuation with inversion recovery (WS-SPAIR) as prepulses and conducted T₁ high-resolution isotropic volume examination (THRIVE).¹ Image processing software can be used to estimate the area and volume of fat and separate the fat and water signals at a visually optimal threshold in the MR image, which requires contrast enhancement between intestinal contents and visceral fat. In 14 volunteers, we evaluated WS-SPAIR and water suppression-spectral presaturation with inversion recovery (WS-SPIR) with respect to the relationship between the flip angle of THRIVE and signal contrast. We used flip angles of 5°, 10°, and 20°. The minimum threshold that allowed exclusion of intestinal contents from the masked region was determined for each technique. The volume and area of the masked region, which included subcutaneous fat, were measured at the umbilicus level. Both volume and area increased with a smaller flip angle. The masked region was larger with WS-SPIR-THRIVE (flip angle 5°). The size of the masked region was determined according to the minimum threshold that allowed exclusion of the intestinal contents from the masked region, expressing the contrast between the intestinal contents and fat in a relative manner. It was speculated that by separating the signals at the threshold, WS-SPIR-THRIVE (flip angle 5°) was a more suitable technique for measuring the area and volume of visceral fat.

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

Introduction

Computed tomographic (CT) estimation of the area of visceral fat at the umbilicus level has been added as a diagnostic criterion for metabolic syndrome (standard area ≥ 100 cm²).

To avoid radiation exposure, we attempted to measure the area and volume of visceral fat using magnetic resonance (MR) imaging.

To diagnose metabolic syndrome, we attempted to measure the volume and area of visceral fat us-

ing T₁ high-resolution isotropic volume examination (THRIVE) in combination with water suppression-spectral attenuation with inversion recovery (WS-SPAIR).¹

We evaluated WS-SPAIR and water suppression-spectral presaturation with inversion recovery (WS-SPIR) techniques with respect to the relationship between the flip angle of THRIVE and signal contrast. Visceral fat is measured by separating it from the intestinal contents using a threshold, which requires an imaging technique that enables enhancement of their contrast resolution. Because the contrast between visceral fat and intestinal contents changed with the flip angle of THRIVE, an at-

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tempt was made to optimize the flip angle.

We used software designed to measure visceral fat based on CT images; visceral fat is separated by dividing the CT values at a threshold. However, the CT values of intestinal contents and fat are often similar because of the partial-volume effect from the mixing of air and water. Measuring the area of visceral fat requires elimination of intestinal contents from the image. When using a CT scan, the volume of visceral fat cannot be measured by simply setting a threshold.¹

We reasoned that we could measure the volume of visceral fat if our technique enabled separation of fat from intestinal contents at the threshold. Compared with measuring the area at the umbilicus level, our technique would appear to reduce more effectively the deviation from intestinal movement, especially of the transverse colon, entering the slice

used for measurement at the umbilicus level.

Materials and Methods

Fourteen volunteers who submitted written consent underwent MR imaging on a 1.5T system (Philips Intra Achieva Nova Dual). All volunteers were examined in a supine position using a SENSE body coil (4-ch). Abdomen and pelvic examination centered on the umbilicus consisted of MR imaging using WS-SPIR (delay time: default, 11-second breath hold)- and WS-SPAIR (delay time: 90 ms, 14-second breath hold)-THRIVE (thickness, 2 mm; overcontiguous slices; echo time [TE], 1.9 ms; repetition time [TR], 3.9 ms; 70 slices). Flip angles for imaging were adjusted to 5°, 10°, and 20° (WS-SPIR, WS-SPAIR 5°, 10°, 20°).

Fifty of 70 slices were selected by excluding the

Fig. 1. Water suppression-spectral attenuation with inversion recovery (WS-SPAIR) T₁ high-resolution isotopic volume examination (THRIVE). **a:** flip angle 5°. The intestinal contents, which appeared as an area of low intensity, demonstrated a marked contrast with visceral fat. **b:** flip angle 10°. Parts of the intestinal contents appeared as areas of high intensity. **c:** flip angle 20°. The intestinal contents, which appeared as an area of high intensity, demonstrated poor contrast with visceral fat. The contrast between visceral fat and intestinal contents was visually confirmed to diminish as the flip angle increased.

10 upper and lower slices and scanned into the workstation (AZE Virtual Place® software) for processing.

Using masked display, the threshold was defined as the minimum value that excluded intestinal contents in the masked region. In the case of intestinal aggregation, when intestinal contents and mesenteric fat could not be discriminated using the information from a single slice, we used the upper and lower slices and traced continuity to distinguish them. After defining the threshold, we measured the “whole volume, no residual intestinal content” (W.V.; volume of the whole masked region including subcutaneous fat) and the “whole area, no

residual intestinal content” (W.A.; area of the whole masked region including subcutaneous fat at the umbilicus level). The contrast between intestinal contents and visceral fat was compared with the results of visual assessment (Fig. 1).

A volunteer whose ratio between signals for fat and intestinal contents were lowest at WS-SPAIR 20° (Fig. 2), and a different volunteer, whose intestinal contents were observed longer in the visual assessment, were selected for further evaluation. Fifty slices each were collected, and intestinal contents were manually surrounded with a frame to measure the “volume of intestinal content” (I.V.).

The data showing the most appropriately masked

Fig. 2. Volunteer A. **a:** Water suppression spectral presaturation with inversion recovery THRIVE flip angle 5° (WS-SPAIR 5°). Although the intestinal contents appeared as an area of high intensity at WS-SPAIR 5°, this figure demonstrates a clear reduction in intensity and improved contrast between intestinal contents and visceral fat. **b:** WS-SPAIR 5°. Parts of the intestinal content appeared as areas of high intensity. **c:** WS-SPAIR 20°. The intestinal contents were shown as an area of high intensity that occasionally exceeded the intensity of visceral fat. At WS-SPAIR 20°, the volume of the intestinal contents, manually surrounded with a frame, was 119 mL. The volume of visceral fat divided according to a visually appropriate threshold at WS-SPAIR 5° was 897 mL. The volume of intestinal contents was 2.6 mL, which accounted for 0.28% of the estimated volume of visceral fat. This ratio was the highest in the 14 cases studied.

visceral fat at WS-SPIR 5° according to visual assessment were selected for further evaluation. The 50 slices were collected and the intestinal contents remaining in the mask were manually surrounded with a frame to measure I.V.

Results

W.V. peaked at WS-SPIR 5° in 11 of 14 cases and at WS-SPAIR 5° in the remaining three; W.A. peaked at WS-SPIR 5° in 12 of the 14 and at WS-SPAIR 5° in the other two. At WS-SPAIR 20°, W.V. reached its minimum value in 12 of the 14 cases, and W.A. reached its minimum value in 13 of the 14. W.V. and W.A. tended to increase at smaller flip angles and measurements when WS-SPIR was larger than under WS-SPAIR. These results indicate that use of a smaller flip angle, which assures sufficient contrast between intestinal contents and fat, is suitable to separate visceral fat when a threshold is set. On the other hand, because of the small difference in intensity between fat and intestinal contents, a larger flip angle reduces the masked region of fat when the threshold is set at a level that enables exclusion of intestinal contents (Figs. 3, 4). These results are consistent with the

results of the visual assessment of the contrast between intestinal contents and visceral fat (Fig. 1).

At WS-SPAIR 20°, intestinal contents were successfully measured in Volunteer A, who had the lowest ratio between signals for fat and intestinal contents (Fig. 2), and Volunteer D, whose intestinal contents were observed longer visually. I.V. was 119 mL in Volunteer A and 115 mL in Volunteer D.

Data obtained at WS-SPIR 5° from Volunteer A demonstrated I.V. remaining in the mask of 50 slices was 2.6 mL, volume of visceral fat was 897 mL, and the ratio of intestinal contents to visceral fat was 0.28%. In 13 of the 14 cases, I.V. was 1 mL or less, and the ratio of the volumes of intestinal contents to visceral fat was 0.1% or less.

Discussion

With respect to intestinal content, examination of flip angle revealed that the intensity of intestinal contents was decreased and differentiation from visceral fat was possible at WS-SPIR at a flip angle of 5°.

Water can be selectively inverted with the SPAIR, SPIR water suppression THRIVE technique, and only the fat signal is excited by impres-

Fig. 3. Whole volume (W.V., no residual intestinal content) mL. We set a minimum threshold that did not allow inclusion of intestinal contents in the masked region and measured the “whole volume, no residual intestinal content” (W.V.: volume of the whole mask region including subcutaneous fat). At WS-SPIR 5°, the maximum values were obtained in 11 of the 14 cases, and the contrast between intestinal contents and visceral fat was clear.

Fig. 4. Whole area (W.A., no residual intestinal content) mm². We set a minimum threshold that did not allow inclusion of the intestinal contents in the mask region and measured the “whole area, no residual intestinal content” (W.A.: area of the whole mask region including subcutaneous fat at the umbilicus level). At WS-SPIR 5°, maximum values were obtained in 12 of the 14 cases, and the contrast between intestinal contents and visceral fat was clear.

sion of the excitation pulse at the point when the T_1 -relaxation of the water signal attains the null point. The T_1 -value of intestinal contents was lower than that of water, although it did not attain a null point, and the signal for intestinal contents could be reduced by lowering the flip angle to 5°.

SPAIR was developed as a fat suppression technique for 3T that was resistant to non-uniform RF.² In SPIR, which allows selective excitation of fat signals at 110°, data are collected after a short inversion time (TI); SPAIR allows excitation at 180° and requires a longer TI. The recommended TI (delay time) for SPAIR is about one third of SPAIR TR (SPAIR pulse repetition time). At this hospital, TI is set at 90 ms. The TI for SPIR is set to the default of about 15 ms. In SPAIR water suppression, a longer TI appears to allow progressive T_1 recovery of tissues other than fat, leading to enhancement of the signal intensity of intestinal contents.

In the future, basic phantom examination will be conducted by changing the flip angle and T_1 value.

In the present study, under the condition of WS-SPIR THRIVE at a flip angle of 5°, the ratio of the volume of intestinal contents remaining in the masked region to the volume divided according to the threshold was a maximum of 0.28%, whereas

the ratios were 0.1% or less in the other cases. This difference can be regarded as an acceptable error range. Our study reveals the potential for measuring the volume of visceral fat by setting a threshold.

Conclusion

Low intensity of intestinal contents at a SPIR water suppression flip angle of 5° and their differentiation from visceral fat by the threshold allowed easy volumetric evaluation of visceral fat.

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