Abdominal Fat: Standardized Technique for Measurement at CT

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The authors estimated abdominal fat distribution on the basis of measurements at computed tomography (CT). The attention range for fat tissue was defined as the interval within the mean plus or minus 2SDs considered to be individual variation. Fat areas found with this method were closely correlated with those obtained by means of the computed planimetric method or with a fixed attenuation range from -190 to -30 HU as the standard of reference. Although the average CT numbers obtained with different scanners were distributed widely, the calculated fat areas almost identical. This method might be a practical and standardized method at CT.

Abdominal obesity, as calculated with indexes such as the waist-to-hip circumference ratio, is related to metabolic disorders and hypertension and to an increased frequency of total mortality and cardiovascular disease (1-3). In recent years, intraabdominal visceral fat accumulation has been suggested as playing an important and etiologic role in these relationship (4-6). Computed tomography (CT) is an optimal technique for the accurate assessment of intraabdominal fat (7,8). We previously developed a method for measuring the fat volume in the human body using this technique (7). Several studies revealed that visceral fat areas from a single scan obtained at the level of the umbilicus (approximately the level of L4 and L5) were highly correlated with the total visceral fat volume (7-9). Accordingly, a technique for the measurement of abdominal fat distribution based on finding at CT may be a practical and widely usable method for the evaluation of visceral fat accumulation, which is one of the important cardiovascular risk factors. In the literature, however, several different attenuation ranges have been used to measure adipose tissue. Since the areas measured on the basis of different attenuation
ranges may not be identical, we developed and evaluated a standardized method for measuring abdominal fat volume with CT.

Materials and Methods

Subjects

Our study population included 120 subjects (60 male and 60 female patients; age range, 15-70 years; mean age, 50 year +/- 9) with a body mass index between 17.3 and 39.1 kg/m² who were in- or outpatients at the Minoh City Hospital. In addition, six male volunteers, aged 32-40 years (mean age, 35 years +/- 5) with a body mass index from 20.0 to 25.8 kg/m² were also included for the evaluation of intra-and interobserver reproducibilities. An additional four male subjects, aged 25-48 years (mean age, 34 years +/- 5) with a body mass index between 20.7 and 29.3 kg/m², were included for the evaluation of interequipment reproducibility. This study was approved by the hospital's subcommittee on human studies, and all of the subjects gave their informed consent before participating in the investigation.

Methods Protocol

CT (TCT-900S Helix; Toshiba, Tokyo, Japan) was performed with all subjects supine (120 kV, 299 mA, section thickness of 5 mm, scanning time of 2 seconds, field of view of 400 mm). Interequipment reproducibility was evaluated with five scanners: TCT-900S Helix, Toshiba; W-2000, Hitachi, Tokyo; Tomo Scan 300, Philips Medical Systems, Tokyo; Pro Seed, GE Yokogawa Medical Systems, Tokyo; and Somatom Plus, Siemens-Asahi Medocal, Tokyo.

In the 120 subjects, subcutaneous and visceral fat areas measured one cross-sectional scan obtained the umbilicus. Figure 1 shows a method for determining the adipose tissue area on a CT scan. A region of interest of the subcutaneous fat layer was defined by tracing its contour on each scan, and the attenuation range of CT numbers (in Hounsfield units) for fat tissue was calculated (Fig 1, part a). A histogram for fat tissue
was computed on the basis of mean attenuation plus or minus 2 SD (Fig 1, part b). Intraperitoneal tissue was defined by tracing its contour on the scan (Fig 1, part c); within that region of interest, tissue with attenuation within the mean plus or minus 2 SD was considered to be the visceral fat area (Fig 1, part d). The pixels with attenuation values in the selected attenuation range were depicted as white. From those white regions, the total fat area was calculated by counting the number of pixels in each; the visceral fat area was subtracted, and the remainder was defined as the subcutaneous fat area.

Results with this method were compared to those with a computerized planimetric method (KL 4300 Digitizer; Graphtec, Tokyo) and with a fixed attenuation range from -190 to -30 HU as the standard of reference, as defined by Sjostrom et al (8) and Kvist et al (9).

Reliability of Method and Statistical Analysis

To determine the relationship between the total, visceral, and subcutaneous fat areas calculated with the different methods, analysis of variance was performed and intraclass and Spearman rank correlations were calculated. To determine intra- and interobserver reproducibilities, analysis of variance was performed for measurements in the six volunteers performed by different radiologic technicians. To evaluate interequipment reproducibility, the visceral fat area in the four volunteers was calculated with five different CT scanners.

Result

The distribution of average CT numbers for fat tissue in the 120 subjects is shown in figure 2. Wide variation was seen among individual values. Accordingly, the fat area was determined on the basis of the area of variation. The Table shows the correlations...
between the areas determined with each method, which were extremely high. Interaobserver variation was tested with measurements in one volunteer made by three observers. Each observer measured the total fat area five times. Error were small (coefficient of variation, 1.7%, 1.5%, and 1.2%), with only slight variation (coefficient of variation range, 0.2%-0.8%). Interobserver variation was tested with measurements in six volunteers made by six observers. Each observer measured the visceral fat area in each volunteer one time. Errors were small (2.0%-4.9%), with only slight variation (mean coefficient of variation, 2.8% + 1.2%). Interequipment variation was tested with measurements in four volunteers made with five CT scanners (Fig 3). The average CT numbers varied widely (Fig 3, top), but the visceral fat areas were almost identical (Fig 3, bottom).

Discussion

In the current study, we developed a practical, standardizes technique for determining the abdominal fat area at CT. Several techniques have been developed to assess intraabdominal visceral fat. Although anthropometric measurements, such as waist-to-hip circumference ratio and sagittal abdominal diameter, are simple and useful indicators of visceral fat accumulation, these indexes are not always accurate (10-13). Ultrasonography (US) is also a technique that is suitable for evaluating intraabdominal fat; the time needed for a single measurement is very short, but reproducibility and accuracy are somewhat poor (14-16). The usefulness of US indexes for changes in fat mass during weight reduction has not been established. Although magnetic resonance (MR) imaging is also a technique that can be used to assess abdominal fat distribution (17, 18), MR imaging equipment is expensive and less available than is CT equipment. Accordingly, CT may be a more commonly used accurate technique for the measurement of visceral fat tissue. One of the limitations of this technique, however, is that it is not applicable in extremely obese subjects because of the weight limits for the table attached to the CT scanner.
The window width at CT defines the fat tissue area. In the literature, numerous window widths have been described to measure adipose tissue. We previously used a window width from -140 to 40 HU (7). Another group used various window widths, such as -190 to -30 HU, -250 to -50 HU, -250 to 30 HU, -130 to -30 HU, and -150 to 50 HU (18). Rossner et al. (19) performed CT measurements with direct morphometric method in a cadaveric study; they reported close agreement among measurements with different window widths (-140 to -40 HU, -190 to -30 HU, -250 to 30 HU) (19). However, the number of subjects in their study was small. In the present study, we observed wide variation among the average CT numbers for fat tissue in many subjects; this result suggests that area determined on the basis of a fixed attenuation range may be subject to error. To our knowledge, there has been no attempt to determine fat area on the basis of a flexible attenuation range.

In the current study, we found that areas determined on the basis of an attenuation range of the mean plus or minus 2 SD are closely correlated with those calculated by means of the computed planimetric method or on the basis of a fixed attenuation range from -190 to -30 HU. We also found high inter- and intraobserver reproducibilities. It might be reasonable to establish an appropriate attenuation range for fat tissue each time measurements are made in an individual.

We also found that average CT numbers for fat tissue varied considerably depending on the CT scanners; thus, fat areas determined on the basis of these measurements in the same subject might not be the same. With our method, however, we found that the fat areas measured in an individual were almost identical, regardless of the scanner used. Consequently, this method may be one of the most practical techniques for determining abdominal fat distribution at CT, with results that can be generalized among many medical institutions.

References
4. Fujioka S, Matsuzawa Y, Tokunaga K, Tarui S. Contribution of intra-abdominal fat accumulation to the impairment of glucose and lipid metabolism in human
