Ultrasound measurements of intraabdominal fat estimate the metabolic syndrome better than do measurements of waist circumference[1,2]

Ronald P Stolk, Rudy Meijer, Willem PTM Mali, Diederick E Grobbee, and Yolanda van der Graaf on behalf of the Secondary Manifestations of Arterial Disease (SMART) Study Group

ABSTRACT

Background: We recently developed an ultrasound technique to estimate intraabdominal fat (IAF). This method is more accurate than measurement of waist and hip circumferences and is simpler and less expensive than computed tomography or magnetic resonance imaging.

Objective: We compared the associations of ultrasound and waist-circumference (WC) measurements of IAF with other components of the metabolic syndrome.

Design: IAF was determined in 600 consecutive participants in the Secondary Manifestations of Arterial Disease (SMART) study. The mean (± SD) age was 56.1 ± 12.6 y, 30.0% of participants were women, and the mean body mass index (BMI; in kg/m^2) was 26.6 ± 4.1.

Results: IAF increased with age (ultrasound: $r = 0.28$; WC: $r = 0.25$; $P < 0.001$ for both). Higher IAF, as measured by ultrasound but not by WC, was independently associated with higher metabolic risk factors. The correlation coefficients between IAF measured by ultrasound and plasma glucose, total cholesterol, HDL cholesterol, and triacylglycerol were 0.13, 0.16, −0.13, and 0.25, respectively (all $P < 0.001$; adjusted for age, sex, and BMI). The corresponding coefficients for IAF measured by WC were 0.17 ($P < 0.001$) and 0.01, −0.06, and 0.05 (all NS).

Conclusions: These results confirm the findings of computed tomography and magnetic resonance imaging investigations. When IAF is measured by ultrasound, the associations are more pronounced than when WC measurements are used and are independent of BMI. This suggests that IAF can be more reliably assessed by ultrasound measurements than by WC measurements. *Am J Clin Nutr* 2003;77:857–60.

KEY WORDS Ultrasonography, intraabdominal fat, waist circumference, metabolic syndrome, Second Manifestations of Arterial Disease (SMART) study

INTRODUCTION

Obesity is associated with increased morbidity and mortality, independent of dyslipidemia, diabetes, and hypertension (1). Intraabdominal fat, however, is probably more important than is overall weight as a cardiovascular risk factor (2, 3).

As first described by Vague in 1956 (4), an android fat distribution (abdominal obesity, or "apple-shaped" body) is related to an increased risk of cardiovascular disease. Intraabdominal fat increases insulin resistance and the related cluster of metabolic risk factors (glucose intolerance or diabetes mellitus, low HDL-cholesterol concentrations, elevated triacylglycerol concentrations, hypertension, and obesity) (5, 6). This cluster was first described by Reaven (5) as "syndrome X" and is also referred to as the "insulin resistance syndrome" or "metabolic syndrome" (7).

Despite the common notion of the relevance of fat distribution, few large-scale epidemiologic studies have been performed on this topic. This is mainly due to the lack of an adequate technique for measuring regional fat in larger-scale epidemiologic research settings. The current gold standard is computed tomography (CT) or magnetic resonance imaging, which are obviously limited because of equipment, costs, and radiation exposure.

We recently developed and validated an ultrasound protocol for the assessment of intraabdominal fat, which does not have the limitations of CT or magnetic resonance imaging (8). We applied this new technique in a clinical study at our hospital to compare the associations of ultrasound and waist-circumference measurements of intraabdominal fat with other components of the metabolic syndrome.

SUBJECTS AND METHODS

The study was conducted within the framework of an ongoing prospective cohort study of patients with a high risk of cardiovascular disease: the Second Manifestations of ARTerial disease (SMART) study (9). All patients visiting the university hospital for the first time with either symptomatic cardiovascular disease (cerebral ischemia, coronary artery disease, peripheral artery disease, or abdominal aortic aneurysm) or a marked cardiovascular disease risk factor (hypertension, dyslipidemia, or diabetes mellitus) were invited to participate in the study. The study was approved by the Ethical Committee of the University Medical Center Utrecht, and written informed consent was obtained from all patients.

[1] From the Julius Center for Health Sciences and Primary Care (RPS, RM, DEG, and YvdG) and the Department of Radiology (RPS, RM, and WPTMM), University Medical Center Utrecht, Netherlands.

[2] Reprints not available. Address correspondence to RP Stolk, Julius Center for Health Sciences and Primary Care D01.335, University Medical Center Utrecht, PO Box 85500, 3501 GA Utrecht, Netherlands. E-mail: r.p.stolk@jc.azu.nl.

Received June 11, 2002.

Accepted for publication October 14, 2002.

The amount of subcutaneous and abdominal adipose tissue was measured anthropometrically and ultrasonographically. The subjects' height and weight were measured while they wore indoor clothes and no shoes. Body mass index (BMI) was calculated as weight (kg) divided by height^2 (m). Waist circumference was measured halfway between the lower rib and the iliac crest, and hip circumference was measured at the level of the greater trochanter (10). Because the associations with the waist-to-hip ratio were similar to those obtained with waist circumference, only the results for the latter are presented. In making the ultrasound measurements of intraabdominal fat, we used the distance between the peritoneum and the lumbar spine. A strict protocol, including the position of and pressure on the transducer, was used. All measurements were performed at the end of a quiet inspiration. Each distance was measured at 3 positions, and each measurement was performed three times. The vertebral column was positioned horizontally. The measurements were done without distortion (by compression) of the abdominal cavity (8). Ultrasonographic measurements were performed with an HDI 3000 (Philips Medical Systems, Eindhoven, Netherlands) with a C 4-2 transducer.

The subjects' blood pressure was measured while they were in the supine position; the mean of 2 measurements was used in the analyses. A venous blood sample was taken to measure total cholesterol, HDL-cholesterol, triacylglycerol, and glucose concentrations with the use of commercial enzymatic dry-chemistry kits (Boehringer Mannheim, Mannheim, Germany). The metabolic syndrome was defined as the existence of ≥ 3 of the following conditions: diabetes mellitus (glucose concentration ≥ 7 mmol/L or physician's diagnosis), hypercholesterolemia (total cholesterol concentration ≥ 6.5 mmol/L), hypertriglyceridemia (triacylglycerol concentration ≥ 2 mmol/L), hypertension (blood pressure ≥ 135/85 mm Hg or physician's diagnosis), and obesity (BMI ≥ 25).

Partial Pearson correlation coefficients, which were adjusted for age, sex, and BMI, were calculated for the associations of the 2 different measures of intraabdominal fat with the metabolic risk factors. Linear regression techniques, which were adjusted for age and sex, were used to compare the different measures of intraabdominal fat between subjects with or without the metabolic syndrome. Logistic regression was used to analyze the associations between the measures of intraabdominal fat and the presence of the metabolic syndrome. Results are presented as odds ratios (and 95% CIs), which are regarded as approximations of relative risks. The use of log-transformed variables did not significantly change the associations. All analyses were performed with SPSS 9.01 (SPSS Inc, Chicago).

RESULTS

Ultrasound measurements were performed in 600 consecutive participants in the SMART study. The clinical characteristics of the study population are shown in **Table 1**. The mean (± SD) intraabdominal fat distances in the men and the women were 9.5 ± 2.5 cm (range: 4.1–17.8 cm) and 8.2 ± 2.5 cm (range: 3.5–15.1 cm), respectively. The corresponding figures for subcutaneous fat were 2.6 ± 1.4 cm (range: 0.3–13.0 cm) and 3.4 ± 1.9 cm (0.8–13.5 cm) in the men and the women, respectively.

Intraabdominal fat increased with age (ultrasound: r = 0.28; waist circumference: r = 0.25; P < 0.001 for both). Compared with the men, the women had a slightly higher BMI (27.2 compared with 26.3; P = 0.04) but less intraabdominal fat (P < 0.001 for both ultrasound and waist circumference) and more subcutaneous fat (P < 0.001). There was no association between BMI and age in the men or the women.

TABLE 1
Clinical characteristics of the study population[1]

Age (y)	56.1 ± 12.6
BMI (kg/m^2)	26.6 ± 4.1
Waist circumference (cm)	93.9 ± 10.8
Waist-to-hip ratio	0.91 ± 0.01
Glucose (mmol/L)	6.7 ± 2.8
Cholesterol (mmol/L)	
Total	5.7 ± 1.3
HDL	1.14 ± 0.35
Triacylglycerols (mmol/L)	2.1 ± 1.4
Systolic blood pressure (mm Hg)	136.3 ± 19.1
Diastolic blood pressure (mm Hg)	79.7 ± 9.8

[1] $\bar{x}$ ± SD. n = 420 M, 180 F.

Higher intraabdominal fat as measured by ultrasound was associated with higher plasma glucose, total cholesterol, and triacylglycerol concentrations and lower HDL-cholesterol concentrations after adjustment for age and sex (**Table 2**). Further adjustment for BMI showed that these associations were independent of weight, in contrast with the associations observed for intraabdominal fat measured by waist circumference (Table 2). Excluding patients who had diabetes mellitus or nonfasting glucose or lipid measurements did not change the correlations. The amount of subcutaneous fat measured by ultrasound was not significantly associated with the metabolic variables. Hip circumference was significantly associated only with glucose, HDL-cholesterol, and triacylglycerol concentrations, but these associations were no longer significant when patients who had nonfasting glucose or lipid measurements were excluded.

Both measures of intraabdominal fat were significant predictors of the presence of the metabolic syndrome, independent of age and sex. After further adjustment for BMI, the odds ratio of the metabolic syndrome for the ultrasound measurement hardly changed (1.19; 95% CI: 1.08, 1.32), whereas the odds ratio for the waist-circumference measurement decreased and was no longer significant (1.02; 95% CI: 0.99, 1.06). The amount of intraabdominal fat was significantly higher in the subjects with the metabolic syndrome than in those without it, and this difference was more pronounced for the ultrasound measurements (10.1 ± 2.4 compared with 8.2 ± 2.3 cm; 18.8%) than for the waist-circumference measurements (98.6 ± 9.6 compared with 90.5 ± 10.6 cm; 8.2%) (P < 0.001 for both comparisons). Larger differences in each of the individual conditions (obesity, diabetes mellitus, hypercholesterolemia, hypertriglyceridemia, or hypertension) between the subjects with or without the metabolic syndrome were also observed for the ultrasound measurements than for the waist-circumference measurements. The difference in waist-circumference measurements of intraabdominal fat between the subjects with or without hypercholesterolemia was not significant (P = 0.1), in contrast with the ultrasound results for the subjects with or without hypercholesterolemia. Subcutaneous fat measured by ultrasound was not significantly related to the presence of the metabolic syndrome.

DISCUSSION

The results of this study show that the well-known associations between intraabdominal fat and metabolic risk factors are more

TABLE 2
Partial Pearson correlation coefficients between intraabdominal fat measured by ultrasound or waist circumference and metabolic risk factors

	Waist circumference[1]	Ultrasound[1]	Waist circumference[2]	Ultrasound[2]
BMI	0.84[3]	0.64[3]	—	—
Glucose	0.21[3]	0.19[3]	0.17[3]	0.13[3]
Cholesterol				
Total	0.10[4]	0.19[3]	0.01	0.16[3]
HDL	−0.27[3]	−0.28[3]	−0.06	−0.13[3]
Triacylglycerols	0.29[3]	0.39[3]	0.05	0.25[3]
Systolic blood pressure	0.05	0.09[4]	0.04	0.09[4]
Diastolic blood pressure	0.11[4]	0.15[3]	0.08	0.12[3]

[1] Adjusted for age and sex.
[2] Adjusted for age, sex, and BMI.
[3] $P < 0.001$.
[4] $P < 0.05$.

pronounced with ultrasound measurements than with conventional anthropometric measurements (waist circumference and waist-to-hip ratio). In contrast with the associations with anthropometric measurements, the associations with ultrasound measurements were independent of BMI.

In clinical and epidemiologic studies, the estimate of intraabdominal fat that is used most often is waist circumference or the ratio of waist and hip circumferences. Although these measures show a good correlation with CT-measured intraabdominal fat, they are less precise than CT and are strongly associated with BMI (11). Ultrasonography has been proposed as a suitable technique to accurately estimate intraabdominal adipose tissue in a research setting (12, 13). Several studies found a good correlation between amounts of intraabdominal adipose tissue measured by ultrasound and amounts measured by CT, but the use of these ultrasonographic measures has been criticized because of their presumed low reproducibility (14). In a validation study in which we used a strict protocol, we showed that the reproducibility of ultrasound measures is of the same magnitude as that of waist-circumference measures (CV: 4–5%) (8). Using the same protocol, we found a strong association between the amount of intraabdominal fat in a single CT slice at L4–L5 (gold standard) and the amount measured by ultrasound (Pearson correlation coefficient = 0.82, $P < 0.001$). For comparison, the correlation between CT measurements and waist-circumference measurements was 0.57 ($P = 0.01$) (8). It should be realized that neither the measurement of waist circumference nor the ultrasound technique directly measures the amount of intraabdominal fat.

The association between intraabdominal fat and insulin resistance was reported in several studies (6, 7, 15). Ultrasound was used in one study, and the same associations with metabolic factors were found when either ultrasound or CT was used (16). Although the association between obesity and insulin resistance is well explained by adipose tissue metabolism, there is no adequate explanation for the strong relation between intraabdominal fat and insulin resistance (17). The most common hypothesis is that intraabdominal adipocytes are more lipolytically active, probably because of their adrenergic receptors. This increases free fatty acids in the portal system, which interfere with insulin metabolism in the liver. According to an alternative hypothesis, the leading force of the clustering of metabolic risk factors for cardiovascular disease is an inherited or acquired decreased insulin sensitivity (18). It has been suggested that the amount of subcutaneous fat may be as important as the amount of intraabdominal fat (19), but this suggestion was not supported by our data.

Although the pathophysiology of the metabolic syndrome is not completely understood, the increased cardiovascular risk associated with the metabolic syndrome is well established (20). A noninvasive technique to assess the amount of intraabdominal fat to quantify this risk may be useful in specifically targeting preventive actions. Especially in a hospital setting, with suitable equipment and trained technicians, ultrasound may be such a technique.

In conclusion, our results show that the well-known associations between intraabdominal fat and metabolic risk factors for cardiovascular disease are more pronounced with ultrasound measurements (using a strict protocol) than with anthropometric measurements (waist circumference and waist-to-hip ratio) and are independent of BMI with ultrasound measurements. This suggests that the amount of intraabdominal fat can be more reliably assessed by ultrasound measurements than by anthropometric measurements.

We thank the ultrasound technicians from the Department of Radiology for their continuing support in making intraabdominal fat measurements. The SMART Study Group consists of the following individuals: Ale Algra, clinical epidemiologist; Jan-Dirk Banga, internist; John D Blankensteijn, vascular surgeon; Bert C Eikelboom, vascular surgeon; Yolanda van der Graaf, clinical epidemiologist; Diederick E Grobbee, clinical epidemiologist; L Jaap Kappelle, neurologist; Willem PTM Mali, radiologist; Anton J Rabelink, internist; Guy EHM Rutten, general practitioner; and Frank LJ Visseren, internist.

RPS performed the data analyses and wrote the first version of the manuscript. RM was responsible for training the ultrasound technicians and for quality control of the ultrasound measurements, and he performed some of the measurements. WPTMM is responsible for the radiology part of the SMART study, including the ultrasound measurements. DEG supervised the data analyses. YvdG is principal investigator of the SMART study and is responsible for the design, conduct, and finances of the study. All authors contributed to the interpretation of the data and the writing of the manuscript and approved the final version of the manuscript. None of the authors had any personal or financial affiliation with any organization involved in the SMART study.

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