Ultrasonography for the Evaluation of Visceral Fat and Cardiovascular Risk

Fernando F. Ribeiro-Filho, Alessandra N. Faria, Oswaldo Kohlmann, Jr, Sérgio Ajzen, Artur B. Ribeiro, Maria Teresa Zanella, Sandra R.G. Ferreira

Abstract—Visceral fat accumulation is associated with increased cardiovascular risk. Clinical evaluation of visceral fat is limited because of the lack of reliable and low-cost methods. To assess the correlation between ultrasonography and computed tomography (CT) for the evaluation of visceral fat, 101 obese women, age 50.5±7.7 years with a body mass index of 39.2±5.4 kg/m², were submitted to ultrasonograph and CT scans. Visceral fat measured by ultrasonography, 1 cm above the umbilical knot, showed a high correlation with CT-determined visceral fat (r=0.67, P<0.0001). The ultrasonograph method showed good reproducibility with an intra-observer variation coefficient of <2%. Both ultrasonograph and CT visceral fat values were correlated with fasting insulin (r=0.29 and r=0.27, P<0.01) and plasma glucose 2 hours after oral glucose load (r=0.22 and r=0.34, P<0.05), indicating that ultrasonography is a useful method to evaluate cardiovascular risk. A significant correlation was also found between visceral fat by CT and serum sodium (r=0.18, P<0.05). A ultrasonograph-determined visceral-to-subcutaneous fat ratio of 2.50 was established as a cutoff value to define patients with abdominal visceral obesity. This value also identified patients with higher levels of plasma glucose, serum insulin and triglycerides and lower levels of HDL-cholesterol, which are metabolic abnormalities characteristic of the metabolic syndrome. Our data demonstrate that ultrasonography is a precise and reliable method for evaluation of visceral fat and identification of patients with adverse metabolic profile. (Hypertension. 2001;38[part 2]:713-717.)

Key Words: obesity ■ ultrasonography ■ computed tomography ■ metabolism ■ cardiovascular diseases

Obesity has become a alarming public health problem because of its increasing prevalence and comorbidities—eg, diabetes, dyslipidemia, and hypertension—that elevate cardiovascular risk of affected people.1 Although pathophysiologic mechanisms linking obesity to those abnormalities were not completely clarified, it is well known that visceral fat accumulation and insulin resistance contribute to metabolic and hemodynamic changes found in obese people.2,3 Such a situation has been called the metabolic syndrome.4 Although some studies have focused on the role of visceral fat for the genesis of metabolic syndrome,5 others have aimed to find methods and their respective cutoff values able to identify obese people at high risk for cardiovascular disease.6,7 Computed tomography (CT) at abdominal level has provided the best estimation of visceral fat,8 and cutoff values have been proposed to predict morbidity.9 Considering the high ionizing radiation exposure, great expense, and low availability of CT, alternative noninvasive methods to quantify regional adiposity have been used in clinical and epidemiological studies. The use of waist circumference and/or waist-to-hip ratio (WHR), body composition by dual-energy x-ray absorptiometry, and more recently abdominal fat deposition by ultrasonography as predictors of cardiovascular risk have been investigated.10,11 Evidence in the literature has suggested that the visceral fat thickness measured by ultrasonography could be a reliable method to quantify visceral fat compared with that of CT.12,13 In addition, ultrasonography-determined visceral-to-subcutaneous fat ratios have also been shown to be highly correlated to CT measurements.14,15 Therefore, this study tested the correlation between CT and ultrasonograph measurements of abdominal adiposity and evaluated the use of the abdominal ultrasonography as an alternative method for identifying patients at high risk for cardiovascular disease.

Methods

Patients

Patients were recruited from the obesity outpatient clinic at the Federal University of São Paulo. Women, age 20 to 65 years, with a body mass index (BMI) ≥30kg/m² were screened for inclusion in the study.1 Exclusion criteria included self-reported diabetes mellitus, severe dyslipidemia (total cholesterol or triglycerides levels ≥7.8 mmol/L and 5.5 mmol/L, respectively), pregnancy, endocrinopathies (eg, Cushing syndrome and hypothyroidism), and weight loss >3 kg during the past 3 months. Patients with hypertension and mild-to-moderate disturbances of lipid profile were not excluded.

Received March 28, 2001; first decision April 27, 2001; revision accepted May 16, 2001.
From the Divisions of Endocrinology (F.F.R.-F., A.N.F., M.T.Z.) and Nephrology (O.K., A.B.R.) and the Departments of Radiology (S.A.) and Preventive Medicine (S.R.G.F.), Federal University of São Paulo, São Paulo, Brazil.
Correspondence to Dr Fernando F Ribeiro Filho, Rua Machado Bittencourt, 300/112, São Paulo, SP Brazil 04044-000. E-mail ffllexa@uol.com.br
© 2001 American Heart Association, Inc.

Hypertension is available at http://www.hypertensionaha.org

713
The study was approved by the Institutional Ethics Committee, and a written informed consent was obtained from all participants.

**Anthropometric Data**

In this cross-sectional study, all participants had their anthropometric data taken by the same investigator. BMI was calculated as weight divided by height squared. Waist circumference was measured at the midpoint between the lateral iliac crest and lowest rib; hip circumference, at the level of the trochanter major. Ambulatory blood pressure (BP) was recorded over a 24-hour period by automatic monitors (SpaceLabs 90202) that were set to record every 15 minutes during the day and every 30 minutes during the night. Time limits for day and night were set to coincide with the patient’s usual sleeping hours. A night BP fall was calculated by the percentage difference between day and night systolic BP.

Intra-abdominal fat area by CT scanning was obtained in a single tomographic slice, at the L4-L5 level, expressed in cm<sup>2</sup>. Using a 3.5-MHz probe located 1 cm from the umbilicus, 2 ultrasonicographic measurements of intra-abdominal fat, defined as the distance between the internal face of retro-abdominal muscle and the anterior wall of the aorta, were taken.<sup>10</sup> Intra-examination variation coefficient was 1.3%. Criteria used to define “visceral obesity” in CT scan was a visceral-to-subcutaneous fat ratio of 0.4, which has been used as an indicator of “central fat distribution.”<sup>17</sup> Cutoff points to define visceral obesity based on ultrasonograph parameters were not available in literature. In this study, the ultrasonograph values corresponding to the CT values of 110 cm<sup>2</sup>, obtained by the receiver operating characteristic (ROC) curve analysis, were used to characterize “visceral obesity” by ultrasonography.<sup>30</sup>

Patients underwent an oral glucose tolerance test with 75 g of glucose. Plasma glucose levels were determined in fasting condition and 30, 60, 90, and 120 minutes after glucose load; fasting insulin levels were also determined. Insulin resistance index was estimated by homeostasis model assessment<sup>18</sup> and glucose area under the curve (AUC).

Plasma glucose was determined by the glucose-oxidase method. Cholesterol contents of lipoprotein fractions, serum triglycerides, uric acid, and apolipoprotein B were measured enzymatically. Insulin was measured by a commercial radioimmunoassay kit (Linco Research Inc).

**Statistical Analysis**

Statistical analysis was performed by using the SPSS software package (version 8.0). Student’s <i>t</i> test and <i>χ</i><sup>2</sup> were used to compare variables between groups. Correlations was tested by the Pearson coefficient; <i>κ</i> statistics were used to assess the concordance between diagnostic criteria for visceral obesity by ultrasonography and CT. Logarithmic transform of visceral fat by CT was used. Data were shown as SEM and SD. Level of significance was set at <i>P</i>&lt;0.05.

**Results**

The 101 patients completed all the steps of the study. The mean age was 50.5±7.7 years, with a predominance of white (56%) and postmenopausal women (61%). The study sample showed a mean BMI of 39.2±5.4 kg/m<sup>2</sup>; 9.9% had glycemic values compatible with diabetes<sup>19</sup> during the oral glucose tolerance test. Ultrasonograph estimations of intra-abdominal fat—distance (Figure 1) and visceral-to-subcutaneous fat ratio—were highly correlated with CT-determined visceral fat area (<i>r</i>=0.67 and <i>r</i>=0.46, respectively; <i>P</i>&lt;0.01). The distance of 2.50 was chosen as the discriminator value (specificity of 75% and sensitivity of 55%) by the ROC curve to correspond to the CT-determined visceral-to-subcutaneous fat ratio of 0.4. Correlations of clinical and laboratory data with visceral fat estimation by both techniques are shown in Table 1. Cardiovascular risk factors implicated in the metabolic syndrome, such as plasma glucose, HDL cholesterol, triglycerides, insulin levels, apolipoprotein B, and uric acid were correlated with visceral fat. Similar coefficients were observed using either technique of visceral fat estimation.

Also, a significant correlation was detected between serum sodium and CT-determined visceral fat (<i>r</i>=0.18, <i>P</i>&lt;0.05). Prevalence of postmenopausal women was similar between visceral and nonvisceral patients defined by both techniques (data not shown).

Patients were stratified as visceral or nonvisceral obese, according to CT and ultrasonography (Table 2). The concordance between criteria of visceral obesity by ultrasonography and CT was 65%, with <i>κ</i> statistics of 0.30 (<i>P</i>&lt;0.01). Patients

**Table 1. Correlation Coefficients of Visceral Fat Estimations (CT and Ultrasonograph techniques) With Clinical and Laboratory Data**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Visceral Fat</th>
<th>CT</th>
<th>Ultrasonography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist circumference</td>
<td>0.53†</td>
<td>0.72†</td>
<td></td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.53†</td>
<td>0.56†</td>
<td></td>
</tr>
<tr>
<td>24-h systolic BP</td>
<td>0.09</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>24-h diastolic BP</td>
<td>0.01</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fasting</td>
<td>0.27*</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>120’</td>
<td>0.34*</td>
<td>0.22*</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.15</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td>-0.26*</td>
<td>-0.27*</td>
<td></td>
</tr>
<tr>
<td>LDL</td>
<td>0.09</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Triglycerides</td>
<td>0.34†</td>
<td>0.32†</td>
<td></td>
</tr>
<tr>
<td>Apolipoprotein B</td>
<td>0.26*</td>
<td>0.26*</td>
<td></td>
</tr>
<tr>
<td>Uric acid</td>
<td>0.16</td>
<td>0.27†</td>
<td></td>
</tr>
<tr>
<td>Fasting insulin</td>
<td>0.27†</td>
<td>0.29†</td>
<td></td>
</tr>
<tr>
<td>Insulin resistance index (HOMA)</td>
<td>0.25*</td>
<td>0.27†</td>
<td></td>
</tr>
<tr>
<td>Glucose AUC</td>
<td>0.36†</td>
<td>0.24*</td>
<td></td>
</tr>
</tbody>
</table>

*<i>P</i>&lt;0.05; †<i>P</i>&lt;0.001.
with visceral obesity by CT and ultrasonography were older than those with nonvisceral obesity (48.1±8.2 versus 53.0±6.2 years and 49.2±8.4 versus 52.7±6.0 years, P<0.05, for CT and ultrasonography, respectively). Both techniques were concordant when identifying association of visceral fat deposition and deterioration of glucose and lipid metabolism. Prevalence rates of diabetes were higher in visceral obese people; insulin resistance index (HOMA) and glucose AUC were also higher in visceral obese people, independently of the estimation method (Figure 2). BP levels did not differ between groups with or without increased visceral fat by any criteria.

**Discussion**

Central obesity has been shown to be an important predictor for metabolic disturbances, including hyperinsulinemia, glucose intolerance, dyslipidemia, hypertension, and cardiovascular disease. Imaging methodologies have been used to assess body fat distribution, and CT is considered the one that best reflects visceral adiposity. Because of limitations for widespread use of CT, other methods were proposed, such as ultrasonography, which was shown to be accurate in directly measuring subcutaneous and intra-abdominal adipose tissue thickness. Our findings support the idea that ultrasonography could be alternatively used to estimate abdominal fat, because a strong correlation between CT and ultrasonography fat estimations was detected, as was reported previously. In addition, the reliability of ultrasonography estimations to predict cardiovascular disease is reinforced by its ability in identifying patients at high risk for metabolic abnormalities. Adverse metabolic profile was verified in people classified as visceral obese by any method. Anthropometric parameters

**TABLE 2. Clinical and Laboratory Data of Obese Patients Classified as Visceral or Nonvisceral According to 2 Different Techniques**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CT</th>
<th>Ultrasonography</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nonvisceral</td>
<td>Visceral</td>
</tr>
<tr>
<td></td>
<td>(n=52)</td>
<td>(n=51)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>40.1±5.9</td>
<td>38.3±4.6</td>
</tr>
<tr>
<td>Fasting plasma glucose, mmol/L</td>
<td>5.3±0.6</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>Fasting Insulin, pmol/L</td>
<td>112.7±61.7</td>
<td>135.0±61.7</td>
</tr>
<tr>
<td>Insulin resistance index, HOMA</td>
<td>3.8±2.2</td>
<td>4.5±2.2</td>
</tr>
<tr>
<td>Glucose AUC, mg·h·dl⁻¹</td>
<td>569.8±114.4</td>
<td>635.9±132.4*</td>
</tr>
<tr>
<td>Prevalence of diabetes, %</td>
<td>3.8</td>
<td>16.3</td>
</tr>
<tr>
<td>Uric acid, mmol/L</td>
<td>0.30±0.08</td>
<td>0.31±0.06</td>
</tr>
<tr>
<td>Cholesterol, mmol/L</td>
<td>Total</td>
<td>5.3±1.0</td>
</tr>
<tr>
<td></td>
<td>HDL</td>
<td>1.20±0.41</td>
</tr>
<tr>
<td></td>
<td>LDL</td>
<td>3.45±0.81</td>
</tr>
<tr>
<td></td>
<td>Apolipoprotein B, g/L</td>
<td>1.19±0.27</td>
</tr>
<tr>
<td></td>
<td>Triglycerides, mmol/L</td>
<td>1.46±0.64</td>
</tr>
<tr>
<td>Sodium, mmol/L</td>
<td>138.7±1.7</td>
<td>140.0±1.5*</td>
</tr>
<tr>
<td>Vigil systolic BP, mm Hg</td>
<td>135.9±18.7</td>
<td>134.3±12.8</td>
</tr>
<tr>
<td>Vigil diastolic BP, mm Hg</td>
<td>84.6±10.9</td>
<td>83.6±8.7</td>
</tr>
<tr>
<td>Vigil heart rate, bpm</td>
<td>87.4±8.6</td>
<td>84.7±11.1</td>
</tr>
<tr>
<td>Sleep systolic BP, mm Hg</td>
<td>124.1±17.6</td>
<td>123.7±14.2</td>
</tr>
<tr>
<td>Sleep diastolic BP, mm Hg</td>
<td>71.8±10.8</td>
<td>72.0±9.7</td>
</tr>
<tr>
<td>Sleep heart rate, bpm</td>
<td>76.3±9.2</td>
<td>71.7±9.9*</td>
</tr>
<tr>
<td>Night systolic blood pressure fall, %</td>
<td>8.4±7.4</td>
<td>7.8±6.5</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>113.4±13.3</td>
<td>114.2±10.2</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.95±0.09</td>
<td>1.00±0.06*</td>
</tr>
<tr>
<td>Ultrasonography</td>
<td>Subcutaneous fat, cm</td>
<td>3.2±1.0</td>
</tr>
<tr>
<td></td>
<td>Visceral fat, cm</td>
<td>6.2±2.2</td>
</tr>
<tr>
<td></td>
<td>Visceral/subcutaneous fat ratio</td>
<td>2.0±0.7</td>
</tr>
<tr>
<td>CT</td>
<td>Subcutaneous fat, cm²</td>
<td>444.7±135.8</td>
</tr>
<tr>
<td></td>
<td>Visceral fat, cm²</td>
<td>117.7±43.8</td>
</tr>
<tr>
<td></td>
<td>Visceral/subcutaneous fat ratio</td>
<td>0.27±0.08</td>
</tr>
</tbody>
</table>

*P<0.05 vs nonvisceral.
continue to offer a fast, easy, and noninvasive method for assessing regional adiposity, particularly in epidemiological studies. However, their relatively low reproducibility may not be adequate for clinical purposes. In contrast, the ultrasonograph variation coefficient is low. In this study, the variation coefficient inter- and intra-observers were <2%, similar to those reported by others.

In contrast to anthropometric and CT methods, cutoff values for ultrasonograph visceral fat measurements to define central obesity were not established yet. In this study, we determined such a value based on CT cutoff points of visceral fat area proposed in the literature by means of ROC curve. The nonvisceral/visceral ratio cutoff of 2.50 was shown to have high specificity but low sensitivity, particularly because our sample was consisted of obese people only.

The results obtained in this study are in agreement with others who suggested a key role for visceral fat in the genesis of insulin resistance syndrome. In fact, significant correlations of visceral adiposity with plasma glucose, insulin levels, and measurements of insulin sensitivity (HOMA and glucose AUC) were detected. Additionally, a worse glycemic profile among visceral obese people was observed compared with nonvisceral obese people diagnosed either by CT or ultrasonography methodology. The association of the main lipid abnormalities—low HDL cholesterol and hypertriglyceridemia—typical of the state of insulin resistance, corroborates to the proposition that ultrasonography is an accurate alternative method to estimate visceral fat. Besides higher triglycerides and lower HDL cholesterol, higher apolipoprotein B, reflecting the atherogenic small dense particles of cholesterol, was also observed among visceral obese group by ultrasonography, which reinforced its role in the identification of people at high risk for cardiovascular disease. Considering that exclusion criteria included diabetes and severe dyslipidemia, it is not surprising that the correlation between visceral fat and glucose and lipid assessments was rather weak.

Although some controversies may exist, epidemiological studies suggest that hyperuricemia is an independent cardiovascular risk factor. It has been shown to be part of the “expanded metabolic syndrome.” In our study, visceral obese patients, identified by both CT and ultrasonograph measurements, showed higher uric acid levels, reflecting the higher degree of insulin resistance associated with visceral adiposity.

The association of visceral obesity with hypertension is well known. Several mechanisms, such as increased sodium reabsorption and sympathetic activity, have been proposed to explain BP elevation in obese patients. In our study, a positive correlation was found between measurements of visceral fat and systolic BP determined by ambulatory BP monitoring, although a significant difference in BP levels between visceral and nonvisceral obese patients could not be shown, possibly because both groups had patients under antihypertensive therapy. The weak but significant correlation between intra-abdominal fat and serum sodium might reflect the increased salt reabsorption associated with visceral obesity and insulin resistance.

Higher heart rate among nonvisceral obese patients was not previously described. We speculate that such finding may be related to their higher leptin levels, because it is well known that leptin is mainly secreted by subcutaneous adipose tissue. In fact, recent evidence suggested that leptin may increase adrenergic tonus.

In summary, our data indicate that ultrasonography is an accurate, noninvasive, reliable method for the assessment of visceral adiposity and identification of obese subjects with adverse cardiovascular profile. Further studies are needed to establish the usefulness of the ultrasonography visceral fat determination to predict cardiovascular morbidity and mortality.

References


