Original Article

Comparison of Visceral Fat Volume and Visceral Fat Area at Umbilical Level Assessed by Multislice Computed Tomography

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Objective: To validate the in-house software that quantify the total abdominal fat volume using multi-detector computed tomography (CT), and define the clinical significance of the capacities of intra-abdominal visceral fat volume (VFV) and subcutaneous fat volume (SFV) to the specific zones, which were scanned by a conventional single-slice CT at the level of umbilicus.

Materials and Methods: Individuals who underwent a 320-slices coronary CT angiogram between January and March 2009 (40 men, 60 women) were recruited. SFV and VFV were measured by semi-automatic method starting at the upmost of the liver down to the lowermost of the pelvis. The capacity inside the muscle walls around abdominal cavity was used to measure intra-abdominal VFV. Calculations of subtracting the VFV from the total abdominal fat capacity will equal to the abdominal SFV. In the same way, the intra-abdominal visceral fat areas (VFA) and subcutaneous fat areas (SFA) were computed by the commercial AccuView software at the level of umbilical.

Results: VFV was correlated positively with VFA measured by the single-slice CT at the level of umbilicus in both genders ($r=0.903$, $p<0.001$ in men and $r=0.786$, $p<0.001$ in women). SFV also showed a positive correlation with SFA in both genders ($r=0.835$, $p<0.001$ in men and $r=0.726$, $p<0.001$ in women).

Conclusion: A new method in measuring the intra-abdominal fat capacities is achieved semi-automatically through helical CT.

Keywords: Visceral fat volume, Visceral fat area, Computed tomography

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Obesity is a major risk factor for many cardiovascular disease (CVD), including hypertension, diabetes, dyslipidemia, and the metabolic syndrome (MetS)[1,2]. Many studies demonstrated that different adipose tissue compartment may be related to differential metabolic risk. The visceral adipose tissue (VAT) presents a higher risk in developing disorders related to obesity than the subcutaneous adipose tissue (SAT) collection does[1-4].

The distribution of regional adipose tissue can be evaluated by many techniques in term of anatomical accuracy. The anthropometric measurement techniques include waist circumference (WC), body mass index (BMI), sagittal abdominal diameter (SAD), and waist-to-hip ratios (WHR) to name some. These techniques have been used as an estimate abdominal adiposity in several sizable epidemiological studies. Although anthropometry is simple and inexpensive, it does not distinguish between the abdominal SAT and the VAT. Furthermore, it has highly variable results[5,6]. The most accurate and direct anatomical methods to quantify VAT are computed tomography (CT) and magnetic resonance imaging (MRI)[3,6]. However, MRI has limitations due to high cost and less available[7].

Multi-detector volume imaging is commonly used to measure the total and regional adipose tissue as a reference. The present study used a single cross-sectional image as a multi-detector volume imagine for presenting the measurement of VAT volume. Many

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Table 1. Clinical profile of the study subjects

	Men		Women	
	n	Mean±SD (range)	n	Mean±SD (range)
Age (year)	40	58±8 (37 to 72)	60	57±8 (40 to 78)
BMI (kg/m^2)	40	25.5±3.1 (20.5 to 34.6)	60	24.1±3.1 (19.6 to 33.3)
WC (cm)	40	91±9 (76.2 to 119.4)	60	84.5±9 (66 to 109.2)
Triglycerides (mg/dL)	37	124.1±62.0	57	124.1±62.0
HDL cholesterol (mg/dL)	37	50.2±11.6	57	54.1±11.6
Total cholesterol (mg/dL)	37	208.5±46.3	57	224.0±54.1
Diabetes mellitus (%)	4	10.0%	11	18.3%
Hypertension (%)	15	37.5%	18	30.0%
Fat area (cm^2)				
Visceral	40	161±73	60	120±58
Subcutaneous	40	195±72	60	231±74
Fat volume (cm^3)				
Visceral	40	6,495±2,069	60	4,964±1,255
Subcutaneous	40	9,177±2,434	60	8,631±1,656

BMI=body mass index; WC=waist circumference; HDL=high-density lipoprotein; SD=standard deviation

studies have shown that visceral fat areas (VFA) from a single scan achieved at the umbilical level (roughly the level of L4 and L5) were vastly correlated with the total visceral fat volume (VFV)[8]. Measurement of visceral fat by direct cross-sectional imaging using CT scan of the abdomen has found a strong association between visceral fat and diabetes in elder adults[4].

The goal of the present study was to determine a correlation of a conventional commercial software that measures fat composition area from single slice of umbilical level with in-house software that quantify fat volume, using multi-detector CT. In addition, the authors assessed the correlation of abdominal adipose tissue to other metabolic risks such as age, BMI, and WC. The association between abdominal adipose tissue and serum lipids level as well as coronary artery calcium (CAC) score were analyzed.

Materials and Methods

Study population

One hundred eighty-four subjects were drawn from those that underwent coronary CT angiogram (CCTA) with 320-slice volume cardiac CT between January and March 2009 at Ramathibodi Hospital, Mahidol University. Of these patients, 84 were excluded from the study due to incomplete image or clinical data. The study subjects consisted of 100 patients, 40 men and 60 women. Demographic and clinical data are presented in Table 1.

The whole abdominal CT scans were performed at the same time as the cardiac CT. The whole abdominal scans were performed in flat position with two arms stretched above the head and during suspended respirations, using a Toshiba Aquilion ONE (Tokyo, Japan). The helical CT scans were obtained with a 200 mA-current, 120 kVp-voltage, and 3-mm slice thickness tube. The scan continued to upper thigh. Additional information including clinical history, body weight, height, age, WC, and serum lipid profile were obtained. Multi-detector CT measurements of CAC, VFA, and subcutaneous fat area (SFA) were also determined for each patient.

The present report was a retrospective cross-sectional analytic study approved by the Institute Research Ethics Committee.

Quantitative measurements of abdominal adipose tissue areas

The intra-abdominal visceral and SAT areas (VFA and SFA) in each individual were determined from an image at the umbilical level by using commercially supplied software (AccuView). SAT was described as the extraperitoneal fat between the muscles and the skin, with attenuation ranging from –150 to –50 HU. The intraperitoneal part with the same density as the subcutaneous fat layer was defined as VAT.

The analyzed images for the present study were performed by qualified observers (radiology

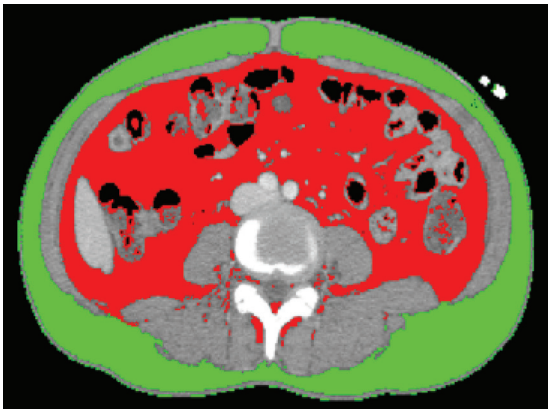

Figure 1. Demonstrates CT measurement of abdominal adipose tissue area at umbilical level by AccuView program, green color represents subcutaneous adipose tissue area (SFA) and red color represents visceral adipose tissue area (VFA).

technicians). The areas of interest of subcutaneous and VAT were determined manually while the VFA and SFA were provided by automatic planimetry (Figure 1).

Quantitative measurements of abdominal adipose tissue volumes

The semi-automatic method was applied as Visionary 3D fat, a plug-in for OsiriX 5.5 (an Open-Source Software for navigating in multidimensional DICOM Images), running on a macOSX. The SFV and VFV were measured across the abdominal imaging volume between the uppermost of the liver and the bottommost of the pelvis or level of femoral head (abdominopelvic region). A semiautomatic segmentation technique was applied, then, adjustments were made manually during the volume was being scanned if necessary.

The VFV was calculated by the volume inside the muscle wall covering the abdominal cavity. Then, the abdominal SFV calculations were made by deducting the VFV from the total abdominal fat volume. Each adipose tissue volumes were calculated in cm^3.

The attenuation range for the fat tissue was set as the interval within the mean plus or minus 2 standard deviations (SDs) of pixel intensities, which was based on visceral. The subcutaneous fats were then calculated. This technique was considered to be an individual variation.

Statistical analysis

The continuous variables were described in the term of mean with SD (mean±SD). Simple correlations were assessed by gender-specific Pearson correlation coefficients. Independent-sample t-test was used for comparing the mean of two variables. All statistical analyses were performed using SPSS software version 17.0. A p-value of less than 0.05 was statistically significant.

Results

The intra-abdominal VFV, measured by volumetric helical CT, showed a positive correlation with the VFA that was measured by CT at umbilical level in both genders ($r=0.903$, $p<0.001$ in men and $r=0.786$, $p<0.001$ in women) (Figure 2). In addition, the intra-abdominal subcutaneous fat volume (SFV) had a positive correlation with SFA in both genders ($r=0.835$, $p<0.001$ in men and $r=0.726$, $p<0.001$ in women) (Figure 3).

SFA, VFA, and VFV showed positive correlation with age in females ($r=0.46$; $p<0.001$, 0.56; $p<0.001$, and 0.28; $p<0.05$, respectively) (Table 2). There was no significant correlation between abdominal adiposity and age in males. Furthermore, BMI and

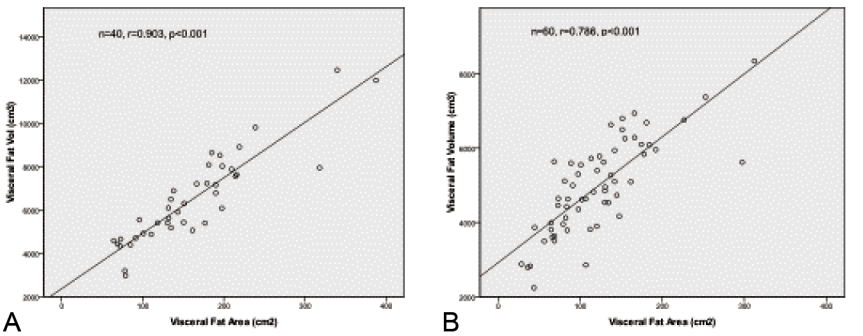

Figure 2. Correlation between visceral fat area and visceral fat volume measured by helical CT in men (A) and women (B).

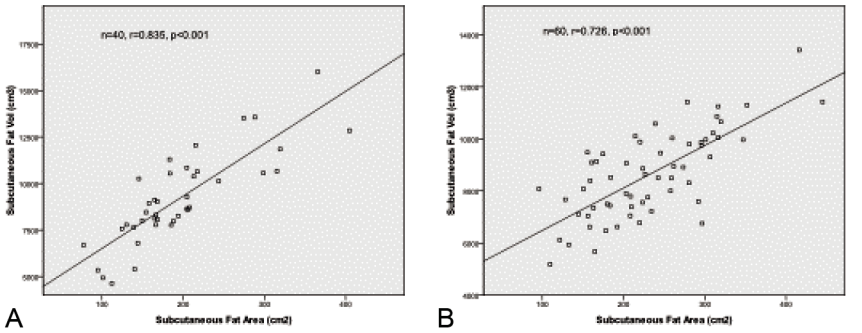

Figure 3. Correlation between subcutaneous fat area and subcutaneous fat volume measured by helical CT in men (A) and women (B).

Table 2. Age-adjusted Pearson correlation coefficients between metabolic risk factors and VFA, SFA, VFV, and SFV

	Men				Women			
	SFA	VFA	SFV	VFV	SFA	VFA	SFV	VFV
Age	0.03	0.002	−0.11	−0.20	0.46**	0.56**	0.25	0.28*
BMI	0.86**	0.84**	0.90**	0.81**	0.58**	0.68**	0.76**	0.62**
WC	0.88**	0.85**	0.92**	0.84**	0.62**	0.60**	0.76**	0.50**
Triglycerides	0.21	0.11	0.21	0.13	−0.25	−0.20	−0.13	−0.13
HDL-C	−0.05	−0.18	−0.18	−0.19	0.94	−0.50	0.01	−0.08
TC	0.20	0.11	0.17	0.15	−0.32	−0.25	−0.16	−0.12
CAC	0.00	0.24	0.09	0.21	−0.12	0.15	−0.11	0.20

SFA=subcutaneous fat areas; VFA=visceral fat areas; SFV=subcutaneous fat volume; VFV=visceral fat volume; BMI=body mass index; WC=waist circumference; HDL-C=high-density lipoprotein cholesterol; TC=total cholesterol; CAC=coronary artery calcium

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)

WC had a strong correlation with all of the adipose tissue compartments measured in area and volume of both genders, but was more pronounced in men. As expected, BMI and WC were strongly correlated with each other (r=0.89 in men, r=0.74 in women; p<0.001; data not shown).

After the age adjustment, there was no significant positive correlation between CAC scores, serum lipid, and abdominal adipose tissue in the present study. However, weak inverse correlation between total cholesterol and SFA in women was seen (r=–0.32, p<0.05).

In hypertensive and diabetic female, the VFA and VFV were considerably higher than in normotensive non-diabetic group (p<0.05), while no significant difference was observed in male patients (Table 3, 4).

Discussion

A new process of assessing intra-abdominal adipose tissue volume using helical CT has been reported[9]. The key discovery of this research was the strong and positive association between the intra-abdominal VFV and SFV (quantified by in-house software) versus the VFA and SFA (quantified by commercial software) in both genders.

The authors also found that SFA, VFA, and VFV were correlated with age in women but not in men. This could be explained as young and middle-aged women tend to store fat in the subcutaneous site at the level of abdomen while older men and older women tend to accumulate fat at the visceral depots[10].

Ohashi et al discovered that SAT and VAT were positively correlated to triglycerides and inversely associated with high-density lipoprotein (HDL) cholesterol in both male and females[2]. There was no significant correlation between serum lipids and abdominal adipose tissue in the present study. These results could be due to the small sample size and most of the patients tend to have normal or slightly abnormal serum lipids and CAC.

Table 3. Independent-sample t-test comparing mean±SD of abdominal adipose tissue among hypertensive and normotensive patients

	Men		p-value	Women		p-value
	HT	Normotension		HT	Normotension	
VFA	189±92	144±53	0.102	162±74	103±39	0.004*
SFA	217±80	181±64	0.154	252±86	223±67	0.216
VFV	7,080±2,391	6,143±1,810	0.203	5,562±1,359	4,708±1,131	0.027*
SFV	9,613±2,722	8,916±2,262	0.413	9,031±1,888	8,460±1,540	0.267

HT=hypertension; SFA=subcutaneous fat areas; VFA=visceral fat areas; SFV=subcutaneous fat volume; VFV=visceral fat volume

* Significant p<0.05

Table 4. Independent-sample t-test comparing mean±SD of abdominal adipose tissue among diabetic and non-diabetic patients

	Men		p-value	Women		p-value
	DM	Non DM		DM	Non DM	
VFA	172±148	160±63	0.885	172±65	109±51	0.010*
SFA	174±132	197±65	0.753	255±83	226±71	0.315
VFV	6,599±3,619	6,483±1,910	0.953	6,061±1,117	4,718±1,158	0.003*
SFV	9,247±4,746	9,170±2,162	0.976	9,061±1,491	8,535±1,691	0.317

DM=diabetes mellitus; SFA=subcutaneous fat areas; VFA=visceral fat areas; SFV=subcutaneous fat volume; VFV=visceral fat volume

* Significant p<0.05

The possibility of significant gender interactions between VAT and diabetes as well as with hypertension was found in prior studies[2,4,11]. The cause of gender differences is uncertain, nonetheless it can be related to the high amount of hepatic free fatty acid delivery resulting from lipolysis from VAT that has been observed in women more than in men[12].

Limitation

First, the present study used a semi-automated software that was time consuming, with approximately two to three hours for each case. Therefore, it is still not suitable for practical use and needs further development. In addition, the small sample size may not be adequate power to detect potential significant relations or differences in some groups.

Conclusion

An acceptable correlation was seen between Visionary 3D fat, a recent semi-automated method for measuring VAT volume in people, and AccuView software, an extensively used and validated commercial software measuring adipose tissue area at umbilical level. Therefore, the most appropriate method for routine screening or evaluating metabolic risk from abdominal adipose tissue distribution and quantification in the authors' hospital is still the single-slice umbilical adipose tissue area measurement because it is faster. However, there are advantages of volumetric adipose tissue measurement, such as in case of obesity treatment follow-up for weight-losing program because of its higher precision. Furthermore, the in-house software is inexpensive compared to the commercial volumetric measurement software.

What is already known on this topic?

Many studies disclosed that the VFA from a single scan done at the umbilical level roughly at the level of L4 and L5 were vastly correlated with the total VFV.

What this study adds?

Intra-abdominal VFV, measured by volumetric helical CT, was shown to be correlated positively with the VFA measured by CT at the umbilical level in both genders.

Conflicts of interest

The authors declare no conflict of interest.

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