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Role of Ultrasonography Compared to Computed Tomography in Measurement of Visceral Adipose Tissue and Subcutaneous Adipose Tissue in Diabetic Overweight and Obese Adolescents

Amr A. Elfattah Hassan Gadalla[1]*, Soha M.Abd El-Dayem[2], Eman Rabie Hassan Fayed[1], Abo El-Magd Mohamed El-Bohy[1]

[1]Department of Radiology, Faculty of medicine, Cairo University, Cairo, Egypt; [2]National Research Center, Medical Research division, Cairo, Egypt.

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***Correspondence:** Amr A. Elfattah Hassan Gadalla, Department of Radiology, Faculty of medicine, Cairo University, Cairo, Egypt. Phone: +201002835721. E-mail: dr_amr722@hotmail.com
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Abstract

BACKGROUND: Ultrasound (US) is considered as a suitable, accurate, safe, and available technique to measure abdominal adipose tissue of low cost compared to other imaging modalities as computed tomography (CT) and magnetic resonance imaging. It is superior to BMI as a monitor for diabesity due to it is ability to differentiate between visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) in wide epidemiological studies.

AIM: The aim of this study is to validate the accuracy of US measurement of VAT and SAT compared to CT and being an accurate safer alternative to CT in the assessment of abdominal VAT and SAT in diabetic overweight and obese adolescent in relation to BMI and duration of DM.

METHODS: This is a cross-section study approved by the Local Ethical Committee. This study was performed in the US and CT units/radiology department of our university. Patients were referred from the national research center through 10 months starting from December 2019 to September 2020. Full written consent was delivered by all patients. One hundred and seven diabetic patients were included, the male to-female ratio of the subjects studied is 1:2. All patients' groups were diabetic with mean duration of DM which was 7.50 ± 3.48 years.

RESULTS: The correlation between the US and CT measurements was high with correlation coefficient 0.921 and 0.988 for VAT and SAT, respectively. Furthermore, there was high significant correlation between the BMI and US and CT measurements of VAT and SAT in all studied groups with correlation coefficient ranging from 0.514 to 0.956.

CONCLUSION: US provides reproducible and valid estimates of VAT and SAT and represents a useful method to assess abdominal fat in large scale epidemiological studies.

Introduction

Diabetes mellitus (DM) has become a highly prevalent disease worldwide and has been recognized as a worldwide epidemic. The prevalence of both DM and obesity has increased worldwide during the past century. It has been predicted that, in 2030, the prevalence will reach more than 7.5% of the world's total population, paralleling the aging and body mass index (BMI) of the population, thus confirming the relationship between obesity and diabetes [1].

Obesity is a major public health problem. Its prevalence has doubled since 1980 in the developed and many developing parts of the world. It is considered a strong determinant of DM, stroke, hypertension, and other numerous chronic diseases, including cancer [2].

As a result of the rising epidemic of obesity, understanding body fat distribution and its clinical implications are critical to timely treatment. Body fat tissue is traditionally distributed into two main compartments with different metabolic characteristics: Subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). While both of these tissue types are important, particular attention has been directed to visceral adiposity due to its association with various medical pathologies [3].

BMI is the most commonly used diagnostic tool for characterizing generalized obesity. Despite the frequent use of BMI, it cannot appreciate differences between subcutaneous and visceral fat compartments [4].

Ultrasound (US) is a suitable technique for estimating subcutaneous and intra-abdominal fat tissue. The time needed for a single measurement is very short. Several studies have shown a good correlation between abdominal US measurement and the amount of intra-abdominal adipose tissue on CT, as well as its usefulness in diagnosing intra-abdominal obesity [5].

At present, the gold standard for quantifying abdominal adipose tissue is computed tomography (CT) or magnetic resonance imaging (MRI). These techniques in field settings are limited due to the associated costs, accessibility issues, contraindications, and possible adverse effects of radiation [6].

The main aim of this study is to validate the accuracy of US measurement of VAT and SAT compared to CT and being an accurate safer alternative to CT in the assessment of abdominal VAT and SAT in diabetic overweight and obese adolescent in relation to BMI and duration of DM.

Methods

This is a cross-section study approved by the Local Ethical Committee. This study was performed in the US and CT units/radiology department of our University. Patients were referred from the national research center through 10 months starting from December 2019 to September 2020. Full written consent was delivered by all patients. One hundred and seven diabetic patients were included, the male-to-female ratio of the subjects studied is 1:2 which is 33.3% (n = 36) males and 66.7% (n = 71) females, the mean age of the subjects was 14.96 ± 3.23 years with age ranged between 8 and 23 years. The mean BMI of subjects was 28.15 ± 2.85 Kg/m^2. All patients' groups were diabetic with mean duration of DM which was 7.50 ± 3.48 years.

Inclusion criteria

Inclusion criteria were diabetic overweight and obese adolescent patients that were included in the study.

Exclusion Criteria

Exclusion criteria were patients with chronic respiratory disorders (cannot hold breath), uncontrolled DM, hypoglycemic coma or DKA, patient with any other hormonal disturbance rather than DM or those on long-term corticosteroids, and any chronic illness patients (i.e., renal-cardiac–respiratory – hepatic – congenital anomalies – rheumatological.).

Physical and demographic parameters of the studied groups are summarized in Table 1.

Table 1: Physical and demographic parameters of the studied groups

Variable	Mean ± SD	Median	Minimum	Maximum
Age	14.96 ± 3.23	15.00	8.00	23.00
BMI	28.15 ± 2.85	27.00	25.30	35.00
Duration of DM	7.50 ± 3.48	7.00	2.00	17.00

BMI: Body mass index, DM: Diabetes mellitus, SD: Standard deviation.

Imaging protocol

The study was done using both Toshiba US device and Toshiba CT device.

VAT and SAT were measured using ultrasonography and CT. Multivariable logistic regression controlling for age and gender was used to evaluate (Figures 1-3).

Abdominal ultrasonography

- Fasting patient.
- At the end of expiration.
- Applying the same probe pressure for all subjects.

Techniques

- A 3.5 MHz convex-array probe and 7.5 MHz linear probe for measuring VAT and SAT, respectively, at 1 cm above the umbilicus.
- SAT was measured with a 7.5 MHz linear probe as the distance from the deep border of the dermis\epidermis layer down to the anterior rectus sheath.
- VAT was measured with a 3.5 MHz convex-array probe as the distance from the posterior rectus sheath at the same level to the anterior aspect of the aorta.
- Each measurement was performed 3 times and the mean of the three successive measures was used for analysis.

Abdominal CT

- The participant is supine.
- In fixed expiration.
- The arms are extended overhead.

Techniques

- CT scan at 125 KV, which scanned a single slice of 10 mm thickness at the level (L4/5 disc).
- VAT and SAT were measured on the CT images by circumscribing the visceral and subcutaneous components manually and using an attenuation range of −190–−30 Hounsfield units to quantify adipose tissue within.

Statistical analysis

Data were coded and entered using the Statistical Package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data were summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Correlations between quantitative variables were done using the Pearson correlation coefficient.

$p < 0.05$ were considered as statistically significant, and <0.01 were considered highly significant.

Graphs were used to illustrate some information.

Results

This study was prospectively carried on 107 patients, the male-to-female ratio of the subjects studied is 1:2 which is 33.3% (n = 36) males and 66.7% (n = 71) females.

The comparisons between ultrasonography and CT in measurement of SAT and VAT in all subgroups reviled, there are a strong correlation between US and CT measurements of subcutaneous and VAT thickness in diabetics ($p < 0.0001$).

In relation to BMI, there is strong correlation between the BMI and US and CT measurements of VAT and SAT in all studied groups ($p < 0.0001$) (Table 2) , however there is a nonsignificant correlation between SAT measurement in both US and CT and the BMI in the same studied group (Table 3).

Table 2: High significant correlation between the body mass index and ultrasonography (US) and computed tomography measurements of VAT and SAT in all studied groups

BMI	VAT (US)	SAT (US)	VAT (CT)	SAT (CT)
r	0.864	0.514	0.956	0.527
p	< 0.001	< 0.001	< 0.001	< 0.001
n	107	107	107	107

BMI: Body mass index, CT: Computed tomography, VAT: Visceral adipose tissue, SAT: Subcutaneous adipose tissue, US: Ultrasonography.

A slightly weaker correlation was obtained for SAT measurement by the US and CT in relation to the BMI among obese subjects (BMI ≥ 30) (Table 3) and in subjects of DM duration equal or less than 5 years (Table 4).

Table 3: High significant correlation between VAT measurement in both US and computed tomography and the body mass index in studied groups of body mass index equal or more than 30

BMI≥30	VAT (US)	SAT (US)	VAT (CT)	SAT (CT)
r	0.758	0.018	0.891	−0.020
p	< 0.001	0.914	< 0.001	0.906
n	37	37	37	37

BMI: Body mass index, CT: Computed tomography, VAT: Visceral adipose tissue, SAT: Subcutaneous adipose tissue, US: Ultrasonography.

Table 4: High significant correlation between the US and computed tomography measurements of VAT with body mass index in studied groups of DM duration equal or less than 5 years; however, non-significant correlation between the US and computed tomography measurements of SAT in the same duration

Duration of DM≤5 years BMI	VAT (US)	SAT (US)	VAT (CT)	SAT (CT)
r	0.796	0.258	0.972	0.239
p	< 0.001	0.185	< 0.001	0.220
n	27	27	27	27

DM: Diabetes mellitus, BMI: Body mass index, CT: Computed tomography, VAT: Visceral adipose tissue, SAT: Subcutaneous adipose tissue, US: Ultrasonography.

There is strong correlation between US and CT measurement of both VAT and SAT in both genders; however, females have slight higher correlation coefficient than males (Table 5).

Table 5: High significant correlation between VAT measurement in US and computed tomography in male and females studied groups

VAT (CT)	VAT (US)
Female	
r	0.927
p	< 0.001
n	71
Male	VAT
r	0.913
p	< 0.001
n	36

CT: Computed tomography, VAT: Visceral adipose tissue, US: Ultrasonography.

Discussion

US has been proposed as a suitable technique to accurately measure abdominal adipose tissue in research settings, which have some advantages such as safety, availability, and low cost. However, some previous validation studies of US have reported inconsistent results [4].

In our study, we found that US is a valid method for assessing VAT and SAT compared to CT measurements of the VAT and SAT area. The correlation between the two methods was high with correlation coefficient 0.921 and 0.988 for VAT and SAT, respectively.

Our results are consistent with the previous study by Kvist *et al*., 2004, which reported modest to high correlations between VAT thickness as assessed by US and VAT measured by CT, with correlation coefficients ranging from 0.67 to 0.91 [4].

Two studies conducted by Fihlo *et al*., 2001 and Armellini *et al*., 1990 reported a modest correlation coefficient of 0.67. However, the study Fihlo *et al*., 2001, was conducted among overweight women with smaller sample size than ours (50 patients) and only female gender, while Armellini *et al*., in 1990, study was on 101 subjects of both genders which also smaller than ours. However, both authors reported slightly higher correlations of 0.71 and 0.74 in more recent studies conducted among 100 and 119 overweight women, respectively (Armellini *et al*., 1993; Fihlo *et al*., 2003) [7].

Other studies by Berker *et al*., 2010 and Koda *et al*., 2007 performed also reported higher correlations of ≥0.79 [1].

In a study by Gradmark *et al*., in 2010, a strong correlation between CT and ultrasonography in the measurement of SAT with a correlation coefficient of 0.93 and ($p < 0.0001$) was reported. A separate study by Bazzocchi *et al*., in 2010, also reported promising results, where the authors demonstrated excellent

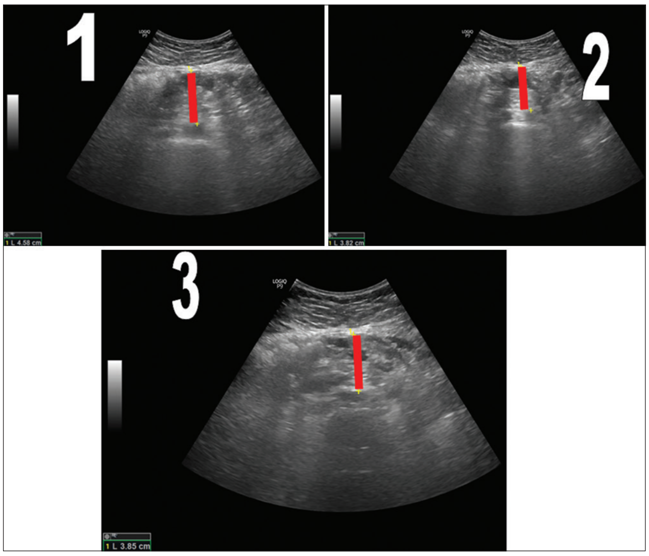

Figure 1: A 17-year-old female patient presented with diabetes mellitus for 6 years duration. Her body mass index was 26.3. Abdominal ultrasonography using 3.5 MHz convex-array probe: Three successive measures of visceral adipose tissue were taken from the posterior rectus sheath to the anterior wall of the aorta (annotated by red lines) with average measure 4.07 cm (1, 2, and 3)

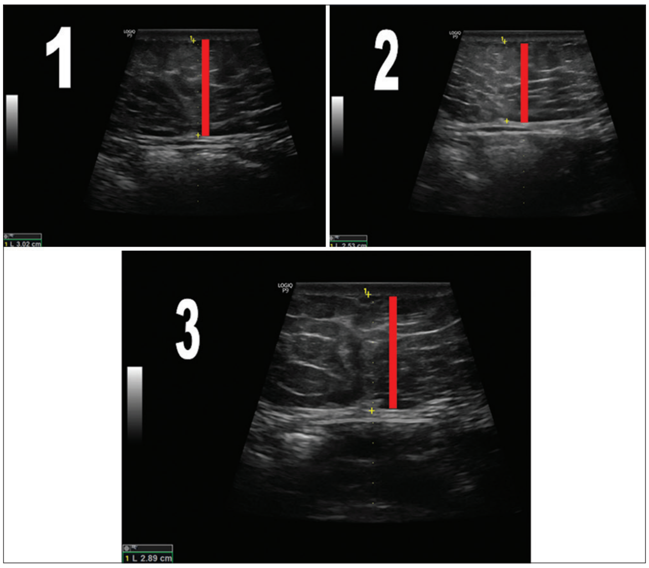

Figure 2: Three successive measures of subcutaneous adipose tissue (SAT) were taken for the same patient using 7.5 MHz linear probe from the hypodermis to the anterior rectus sheath (annotated by red lines) with average measure 2.8 cm (1, 2 and 3)

correlations between abdominal SAT thickness measurements with US and CT (mean correlation coefficient = 0.94–0.96) [8].

As regard SAT measurements, in subgroup analyses stratified by BMI, we found lower correlations between the two methods for obese than overweight subjects. A slightly weaker correlation for SAT measurement by the US and CT in relation to the BMI being of correlation coefficient of 0.018 and 0.020 among obese subjects (BMI ≥ 30) compared to an overweight correlation of 0.323 and 0.325 US and CT, respectively. One possible reason for a weaker correlation among obese than overweight subjects is that measuring a greater distance is more prone to measurement error. In addition, in our study, BMI strata were small and the number of subjects that fell into each stratum was not equally distributed. We believe if the study conducted on a larger sample better correlation could be achieved.

In general, we found a highly significant correlation between the BMI and US and CT measurements of VAT and SAT in all studied groups, the overall correlation ranging from 0.514 to 0.956. Similar high correlations were found in studies by Hirooka *et al*., 2005 and Stolk *et al.*, 2001 that used same protocol as our study that included instructions to perform the examination at the end of a normal exhalation and to place a minimal amount of pressure on the probe during the US examination, they both showed that the measurement of the visceral and subcutaneous fat using the US provided results as effective as CT. It was proven to be a useful method [8].

Another subgroup analysis stratified by the duration of the DM, our study showed high significant correlation between the US and CT measurements of VAT with BMI in studied groups of DM duration equal or less than 5 years with correlation coefficient 0.796 and 0.972 for the US and CT, respectively; however, no significant correlation was found between the US and CT measurements of SAT in the same studied group, with a correlation coefficient of 0.258 and 0.239 for the US and CT, respectively.

In studied subgroup of DM duration more than 5 years, our study showed a highly significant correlation between the US and CT measurements of both VAT and SAT with BMI with correlation coefficient 0.878 and 0.950 for the US and CT, respectively, in VAT measurement and 0.518 and 0.537 for US and CT in SAT measurement.

Similar correlations were found in a study by Norris *et al.*, 2009 which proved that VAT is a good predictor for incident type 2 diabetes than SAT, with evidence of a stronger association of VAT with type 2 diabetes among women and it is sensitivity increases with increased duration of diabetes [9].

Another study by Philipsen *et al.*, in 2013, proved that both visceral and subcutaneous fat could be estimated with ultrasonography with adequate intra- and interobserver reproducibility by clinical researchers with limited training, making it a feasible method of assessing abdominal fat distribution in a population at high risk of diabetes in wide epidemiological studies.

Our final subgroup analyses were stratified by gender (females and males diabetics). We found a high significant correlation between VAT measurement in the US and CT and also between SAT measurement in the US and CT in female studied group with $p < 0.001$ for both VAT and SAT with correlation coefficient 0.927 and 0.986 for VAT and SAT, respectively [10].

Furthermore, a highly significant correlation

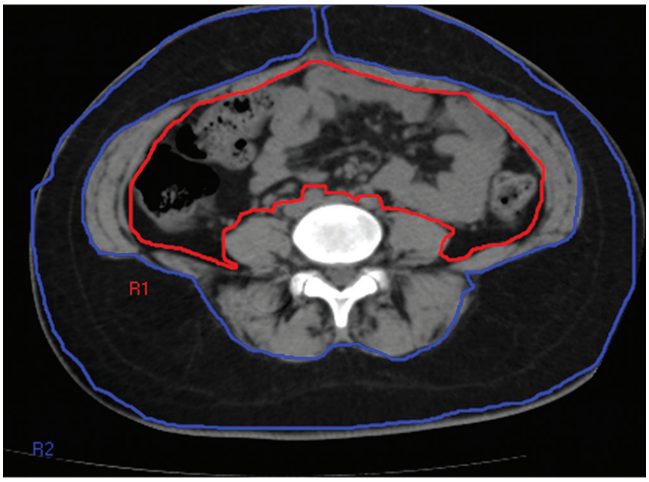

Figure 3: Computed tomography (CT) for the same patient: On a single slice at L4/5 level image, measurement of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) by CT (R_1) represents VAT area measures 126.84 cm^2 with mean attenuation value about −80.14 HU (R_2) represents SAT area measures about 250.89 cm^2 with mean attenuation value about −119.03 HU

between VAT and SAT measurement in the US and CT in male studied group with $p < 0.001$ for both and correlation coefficient 0.927 and 0.992 for VAT and SAT, respectively. Similarly, a high correlation was proven in Dhaliwal *et al*., 2019 study [11].

Although our study reported encouraging results regarding US as a safer and cheaper alternative for CT, the US method's main limitations include the requirement of somewhat experienced technicians with considerable skills. Furthermore, the US measurements of the SAT were less valid in obese people compared to overweight people. In addition, the US examination is of a higher cost compared to anthropometric methods as BMI and waist circumference measurement. However, it is more accurate than them and of lower cost compared to imaging methods such as CT and MRI.

Conclusion

US is an easy procedure with a high diagnostic performance that can be an accurate safer alternative to CT in assessing abdominal VAT and SAT in diabetic overweight and obese adolescent in relation to BMI and duration of DM.

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