Correlation of Abdominal Adipose Tissue distribution on MRI with anthropometric measurements in Diabetic patients

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Authors: M. Mantatzis, A. Chatzistefanou, A. Delistamatis, T. Milousis, D. Papachristou, P. Prassopoulos; Alexandroupoli/GR
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Purpose

Obesity has become a major health problem in both developed and developing countries since it is strictly related with the modern style of life. Increased body mass index and especially increased visceral fat, is associated with diabetes - metabolic syndrome and its complications, namely coronary heart disease and stroke. Quantification of obesity and adipose tissue (AT) distribution within the body is fundamental for the evaluation of patients with diabetes - metabolic syndrome. A rough estimation of AT is usually performed by simple anthropometric measurements, including body mass index (BMI) for rough estimation of total body fat, waist circumference (WC) for visceral AT (VAT), hip circumference for subcutaneous AT (SAT) and waist to hip ratio (WHR) [1]. These measurements can be easily acquired, but they are not precise, they may suffer from systematic errors [2], and they cannot accurately assess the most crucial AT compartment that is the visceral AT (VAT), proven to be closely related with metabolic syndrome[3, 4]. Various strategies for AT assessment on imaging have been proposed, including measurements of head-to-toes body fat, of whole abdominal fat, or of fat on a single-slice CT or MRI at different predetermined levels in the abdomen[5-10]. However, there is no consensus on the most appropriate measurement methodology on imaging examinations. Our purpose is to introduce a simple MRI protocol for quantitative assessment of intra-peritoneal, retroperitoneal and subcutaneous AT and to correlate AT distribution with anthropometric measurements in diabetic individuals.
Methods and Materials

Thirty eight (38) consecutive newly diagnosed male diabetic patients underwent abdominal MRI on a Signa Horizon LX 1.0 T magnetic resonance unit (GE Medical Systems, Milwaukee USA), in a supine position using a body coil. Informed consent was obtained from all individuals. A 3D T1 spoiled gradient echo (SPGR) sequence was obtained through the abdomen (TR=9.4-9.5ms, TE=1.9-2.0ms, flip angle: 30o FOV=380X380 - 480X480 mm, slice thickness of 8mm) and an axial T1-weighted FSE acquisition at the hip levels (TR= 340, TE= 12, slice width: 6mm, FOV=380X380 - 480X480 mm) were acquired and transferred to a pc workstation for AT measurements.

Anthropometric measurements included weight, height, BMI, waist and hip circumference, waist to hip ratio (WHR), femur length, waist to femur ratio, waist to height ratio, arm span and skin fold thickness. Body weight was calculated to the nearest 0.1 kg with patients wearing light clothing and no shoes and height was calculated to the nearest 1 cm. Waist and hip circumferences of subjects in standing position were measured using a soft tape. Maximal waist circumference was measured between the lower rib margin and the iliac crest. Hip circumference was defined as the maximal body perimeter over the buttocks. Arm span was measured with the individual in standing position having both hands in abduction and femur length was measured in the anterior surface from anterior superior iliac spine to the center of patella. Thickness of triceps skin fold was measured using a suitable instrument. Waist to hip, waist to height and waist to femur ratios were calculated from the derived relevant data. BMI was calculated using the formula BMI=height/weight², expressed in kg/m². Finally, body fat accumulation was estimated by bioimpedance analysis using OMRON BF300 Body Fat Monitor (Matsusaka, Japan).

Each image was processed by dedicated software developed on purpose for semi-automatic measurement of adipose tissue. The software processed DICOM images after conversion to 8-bit grey-scale images. Each pixel was labeled as fat or non-fat by applying a threshold to the brightness of each pixel. "Bright" pixels that corresponded to AT were displayed in red (Fig. 1 on page 5). The anatomic regions where the AT was to be estimated, namely subcutaneous, visceral, and retroperitoneal were outlined manually by the operator. To measure the subcutaneous AT, the external margin of the abdominal muscles was traced (Fig. 2 on page 5), AT pixels outside tracing were automatically labeled -calculated and results were expressed as surface (mm²) and volume (mm³) using the DICOM information of the sequence (pixel size, slice thickness). Visceral (intraperitoneal - retroperitoneal) AT pixels were labeled - calculated after tracing of the inner margin of abdominal/back muscles on all abdominal images (Fig. 3 on page 6 Fig. 4 on page 7). Areas that included within visceral compartment exhibiting high signal intensity but not representing adipose tissue, were meticulously excluded during segmentation (Fig. 5 on page 8 Fig. 6 on page 9). At the hips, the outer border of abdominal and gluteal muscles was traced and the pixels outside tracing were calculated as subcutaneous AT (Fig. 7 on page 10 Fig. 8 on page 11, Fig. 9 on
Accordingly, the AT volume for each anatomic compartment was recorded in each slice. The sum of these volumes was referred as "total AT" for each selected slice. Subsequently, the average visceral, subcutaneous and total fat was calculated from the corresponding fat compartments in each slice. The average measurements and the measurements at L2-L3, L3-L4 and L4-L5 intervertebral disk - selected using the scanogram - were transferred to the logistic spreadsheet for the statistical analysis.

In fifteen (15) patients all measurements were repeated on a workstation (Centricity, GE Medical Systems, Milwaukee USA) for the evaluation of the accuracy of our software in measuring fat tissue volumes.

Data were assembled in an excel 2010 spreadsheet (Microsoft Corp, USA) and were statistically analyzed using the Statistical Package for the Social Sciences (SPSS version 17.0, Inc., Chicago, IL, USA) and were presented as group means ± standard deviation (SD). AT volumes calculated by MRI were correlated with anthropometric measurements using Pearson product-moment correlation coefficients. To evaluate the accuracy of the specific software in measuring adipose tissue compartments we used the Wilcoxon non-parametric test between automatic and manual measurements. Unpaired t-test was applied to compare the mean volumes of AT compartments between groups A and B, since data were normally distributed. The power of the used statistic methods was assessed with study size 2.0 (CreoStat, Frolunda, Sweden.)
Fig. 1: High signal intensity adipose tissue (AT) is depicted in the subcutaneous, intraperitoneal and retroperitoneal compartments. Fat signal intensity pixels are labeled after thresholding and measured in compartments outlined by the operator.

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**Fig. 2:** Abdominal subcutaneous AT compartment (in red) is clearly separated from visceral fat and intramuscular fat (in blue).

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**Fig. 3:** Visceral AT compartment separated with a line running the inner border of abdominal muscles and anterior border of vertebral columna and para-vertebral structures.

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**Fig. 4:** Intraperitoneal and retroperitoneal AT compartments are separated with a line running posterior to ascending colon, small intestine and descending colon, anterior to the pancreas and great vessels.

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Fig. 5: Axial slice through the lower kidney poles. The area of abdominal AT is measured 183620.55 mm²

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Fig. 6: Bright intestinal material in fig.5, rendered 20370.59 mm$^2$ after segmentation, which is more than 10% of abdominal fat and should not be included in AT measurements.

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**Fig. 7:** Axial T1-weighted FSE at the hip level. Pixels representing AT are bright

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Fig. 8: After thresholding bright pixels labeled with red color

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Fig. 9: After manual anatomic segmentation, subcutaneous fat pixels are measured, while intraabdominal AT as well as intramuscular and bone marrow AT are excluded.

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Table 1 on page 15 presents the mean values ± standard deviations of anthropometric measurements and of AT volumes measured by MRI in different anatomic compartments and various levels.

Correlations between anthropometric measurements and AT measurements on MRI are presented in Table 2 on page 15. WC exhibited best correlation with the sum of abdominal AT (visceral+subcutaneous, r=0.88, Fig. 10 on page 16) and with AT in L2-L3 level (r=0.88). Similarly, HC exhibited the best correlation with AT at the hips measured on MRI (r=0.88, Fig. 11 on page 17). However, WHR showed poor to moderate correlation with AT measurements on MRI (0.33 < r < 0.736, 0.001 < p < 0.05) and poor correlation with the VAT/SAT ratio on MRI (r=0.36, p<0.001). BMI demonstrated the best correlation with AT at L2-L3 level (r=0.83). BMI and sum of abdominal AT exhibited significant correlation (r=0.78). Body Fat percentage most significantly correlated with the sum of abdominal AT (r=0.69) and with AT in L2-L3 level (r=0.72). The L2-L5 VAT volume exhibited correlation close to the highest correlation levels observed and better than the rest single levels. Correlations of the rest anthropometric measurements with measurements of AT on MR images were either statistically insignificant or exhibited weak correlations.

Diabetics exhibited a larger amount of VAT than the control group at all levels, [average VAT (T-test=2.184, p=0.049, Fig. 12 on page 18) and VAT at the L3-L4 level (T-test=2.002, p=0.043, Fig. 13 on page 19)]. Similarly, diabetics had increased amount of retroperitoneal AT than control group at L2-L3 level (T-test=2.81, p=0.005) and at L3-L4 level (t-test=2.26, p=0.027). Subcutaneous AT did not differ, at any level, between the two groups on MRI.

The dedicated software for AT measurements provided similar results with manual measurements performed on the workstation; there were no statistical differences between the two sets of measurements (Wilcoxon z=-1.44, p=0.14) and the differences of mean values were less than 2%. Power of the analysis was 0.8 for the t-test concerning retroperitoneal space differences, and more than 0.9 for the most of the Pearson's Correlation tests.
**Table 1: Anthropometric measurements**

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<table>
<thead>
<tr>
<th>AT Average</th>
<th>AT Average</th>
<th>Periton. AT Average</th>
<th>Total AT (SAT+VAT)</th>
<th>SAT L2-L3</th>
<th>VAT L2-L3</th>
<th>+VAT L2-L3</th>
<th>SAT L3-L4</th>
<th>VAT L3-L4</th>
<th>+VAT L3-L4</th>
<th>SAT L4-L5</th>
<th>VAT L4-L5</th>
<th>+VAT L4-L5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist Circum.</td>
<td>BMI</td>
<td>Hip Circumf.</td>
<td>WHR</td>
<td>BODY FAT %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.708</td>
<td>0.785</td>
<td>0.692</td>
<td>0.733</td>
<td>0.856</td>
<td>0.850</td>
<td>0.138</td>
<td>0.333</td>
<td>0.565</td>
<td>0.644</td>
<td>0.682</td>
<td>0.672</td>
<td>0.536</td>
</tr>
</tbody>
</table>

Table 2: Correlations between anthropometric measurements and AT compartments

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Fig. 10: A graph illustrates the correlation between Waist circumference and AT measurements

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Fig. 11: A graph illustrates the correlation between Hip circumference and Subcutaneous AT measurements at this level

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**Fig. 12:** Boxplot diagram representing difference in mean values of average visceral AT at L2-L5 level, between diabetics and non-diabetics. The statistical significance of difference was

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Fig. 13

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Conclusion

MR Imaging may disserves a major role in the research of metabolic syndrome, since it may render accurate measurements of fat in various body compartments. Simple and quick MR protocols can be applied for this purpose. A set of limited number of images through the abdomen at the level of L3 and L4 vertebrae is proposed as representative of the distribution of fat in the body and is preferable than a single slice. This study supports the theory that VAT is important in metabolic syndrome and the use of MRI allows for a more accurate quantification of differences in fat distributions between diabetics and normal individuals.
References


Personal Information

Michalis Mantatzis, MD, phD
Lecturer in Radiology - Neuroradiology
Democritus University of Thrace
Radiology Department of University Hospital of Alexandroupolis,
Email:mmantatz@med.duth.gr
Address:
Michalis Mantatzis, MD, phD
Opsikiou 1
681 00, Alexandroupolis
Greece

Alexandros Chatzistefanou, MD
Radiologist
Democritus University of Thrace
Radiology Department of University Hospital of Alexandroupolis,
Email:kapakous@hotmail.com
Address:
Alexandros Chatzistefanou, MD
University Hospital of Alexandroupolis, Dept of Radiology
Dragana
681 00, Alexandroupolis
Greece
Andreas Delistamatis
Democritus University of Thrace
Radiology Department of University Hospital of Alexandroupolis,
Email: adelistamatis@gmail.com
Address:

Andreas Delistamatis
University Hospital of Alexandroupolis, Radiology Deptment
Dragana 681 00, Alexandroupolis
Greece

Thanos Milousis, MD
Democritus University of Thrace
Internal Medicine and Endocrinology Department of University Hospital of
Alexandroupolis
Email: thanosdr15@yahoo.gr
Address:
Thanos Milousis
University Hospital of Alexandroupolis, Dept of Internal Medicine
Dragana
681 00, Alexandroupolis
Greece

Dimitrios N.Papachristou, Associate Professor
Democritus University of Thrace
Department of Endocrinology, University Hospital of Alexandroupolis
Email: profpapachristoud@yahoo.gr
Address: Dimitriou Soutsou 48, 11521, Athens, Greece
Tel: +030 210 6429680, mobile +030 6932 649401
Fax: +030 210 6429165

Panos Prassopoulos, Professor and Chairman
Democritus University of Thrace
Radiology Department of University Hospital of Alexandroupolis Address:
Email: pprasopo@med.duth.gr
Address:
Prof. Panos Prassopoulos
Medical School of Thrace
University Hospital of Alexandroupolis, Deptm of Radiology
681 00, Dragana - Alexandroupolis
Greece
Fax: +3025510-30469
Phone: +3025510-76527