Does the visceral fat tissue show better correlation with the fatty replacement of the pancreas than with BMI?

**Visseral Yağ Dokusu Pankreasın Yağlı Replasmanı ile BMI'dan Daha İyi Korelasyon Gösterir mi?**

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**Abstract**

**Objective:** Obesity is a risk factor for fatty replacement of the pancreas. We aimed to investigate whether there is a better correlation between the visceral fat tissue and the fatty infiltration of the pancreas than with the BMI.

**Materials and Methods:** One hundred-eighteen patients were visually divided into three groups according to the pattern of the fatty infiltration of the pancreas. Group 0 (n=70) has no fatty infiltration, Group 1 (n=23) has fatty infiltration on the head only, and Group 2 (n=25) has fatty infiltration on the entire pancreas. Additionally, the attenuation numbers (HU) were measured separately at the head, body and tail of the pancreas on contrast-enhanced Computed Tomography CT. The sum of the attenuation number of each part of the pancreas was calculated as the attenuation number of the pancreas. A CT-scan was used to calculate the visceral fat area (cm²). Correlation coefficients were determined between the visceral fat area and the pancreatic attenuation number. The body mass index (BMI) was also used to estimate the amount of abdominal fat.

**Results:** The visceral fat area showed a stronger correlation with the attenuation number of the pancreas than the BMI (r=-0.552, r=-0.345 and p=0.0001, respectively). The difference existed only between the Groups 0 and 1 (p=0.0001) or Groups 0 and 2 (p=0.0001) in terms of visceral fat area. The difference existed only between Group 0 and Group 2 in terms of BMI (p=0.0006).

**Conclusions:** The visceral fat tissue area has a stronger correlation than the BMI in the fatty infiltration of the pancreas.

**Key Words:** Fatty infiltration, Multidetector computed tomography, pancreas, pancreatic lipomatosis, visceral fat

**Introduction**

Pancreatic lipomatosis or fatty replacement of the pancreas is the most frequent pathologic finding in the adult pancreas. Fatty replacement may be uniform, unevenly distributed in the pancreas, or confined to one region of the pancreas (focal fatty infiltration) [1-13].

Obesity is an important risk factor in diabetes mellitus, hypertension, hyperlipidemia, and cardiovascular diseases. The distribution disorder of fatty tissue, especially with the higher accumulation of visceral fat among various kinds of obesity, complicates metabolic disorders; this has been reported as visceral fat syndrome. Obesity is also known to be a risk factor of fatty replacement of the pancreas [1-4, 6-13].

The body mass index (BMI) is simple to obtain and provides a direct measure of being underweight or overweight. In this study, the BMI was also used to estimate the amount of abdominal fat [14].

The visceral fat area of females and males differ even if they have the same values of BMI [15].

To our knowledge, the relationship between the amount of visceral fat tissue and fatty replacement of the pancreas has not been studied on CT. The purpose of the study was to investigate whether the visceral fat area is related to the fatty infiltration of the pancreas. A further aim was to determine whether there was any difference in terms of the visceral fat area among the groups having different patterns of fatty infiltration of the pancreas.

**Materials and Methods**

This retrospective evaluation was performed after obtaining consent from the institutional review board of our hospital; the informed consents of the participants were not required. One hundred-eighteen cases who were consecutively referred to...
our department for CT examination of the upper abdomen for different reasons between April 2008 and June 2008 were enrolled in the study. Patients who had a history of documented pancreatic and peripancreatic disease and those who had abdomen surgery were excluded from the study. Also, patients who had clinical or laboratory evidence of pancreatic disease were excluded from the study. The age, gender, weight, and height of all the subjects were recorded, and the BMI was calculated as the weight (kg) divided by the square of the height (m²) (weight (kg)/ height² (m²)).

The patients consisted of 72 men and 46 women with a mean age of 53 years (range 18-84 years). Scanning was performed with a 16-slice multidetector-row CT scanner (MDCT) (Lightspeed16, General Electric Medical Systems, Milwaukee, Wis., USA). Scan parameters were as follows: detector collimation setting of 16x0.6 mm, 120 kVp, 180-350 mA, and gantry rotation time of 0.5 sec. For diagnostic reading, a 2.5-mm slice thickness and a 2.5-mm reconstruction interval were used. All the subjects received water containing oral contrast material (meglumine sodium amidotrizoate (Urographin, Schering, Spain)) before the examination. The scanning protocol consists of an initial unenhanced study with a 5-mm collimation. Subsequently, an intravenous contrast injection of 90–110 ml of nonionic iodinated contrast material containing 350 mg of iodine per milliliter was performed through an 18 G cannula placed into the antecubital vein at a rate of 3 ml/sec using a power injector. Portal phase imaging was initiated with a 60-sec delay. The acquired images were transferred to the advanced workstation (Advantage Workstation, AW 4.2, GE Medical Systems, Waukesha, WI).

All unenhanced and contrast-enhanced portal phase images in the axial plane were retrospectively reviewed using real-time scrolling on a workstation by a radiologist experienced in abdominal evaluations. Portal phase CT images were used for the measurement of the enhancement of pancreas because a clear distinction can be made between the splenic and superior mesenteric veins and the contour of the pancreas; thus, erroneously adding the veins to the diameters of the pancreas was likely avoided. The measurements were made according to the methods reported by Kolmannskog et al [6].

First, the radiologist evaluated the CT scans visually to determine whether there was a fatty infiltration of the pancreas. If the answer was yes, then it was decided based on the scans whether the entire pancreas or only the head was involved by fatty infiltration. Consequently, the patients were grouped into 3 categories visually on the basis of the pattern of the fatty infiltration.

Secondly, a region-of-interest (ROI) in the shape of a circle was set as large as possible on the each part of the pancreas (head, body and tail) to define the CT attenuation number (HU) of the pancreas. The sum of the attenuation number of each part of the pancreas was calculated as the CT attenuation number of the pancreas.

In a total of 118 cases, subcutaneous and visceral fat areas were measured as described by Yoshizumi et al. [15] on one cross-sectional image at the level of the umbilicus. A window width from -190 to -30 HU was used as the standard of reference. First, the total fat area was measured, and, then, the subcutaneous fat area was subtracted. The remaining area was defined as the visceral fat area.

Statistical analysis

Statistical analysis was performed with a commercially available statistical software (SPSS, version 11.5 for Windows; SPSS, Chicago, Il). Numeric values are expressed as mean ± standard deviation (SD). The Kolmogorov-Smirnov test was performed to assess normality for age distributions between women and men. Pearson correlation coefficients of variables such as visceral fat area and BMI were calculated. Correlation coefficients ≥0.7; <0.5 to <0.69; >0.3 to <0.49; >0.1 to <0.29; and >0.01 to <0.09 were interpreted as indicators of very strong, substantial, moderate, low, and negligible associations, respectively. The significance of differences between correlations was tested with the Hotelling t-test. We performed an analysis of covariance (ANCOVA) for visceral fat area and BMI in the groups having different patterns of fatty infiltration of the pancreas, using age as the covariate. A p value less than 0.05 indicated a statistically significant difference.

Results

A summary of the patient’s characteristics of the enrolled patients in each group is given in Table 1. There was a wide range of values for the BMI in the study subjects, from 18.6 to 48.4 kg/m². We did not find fatty infiltration of the pancreas in 70 patients visually; these patients were considered as Group 0. Forty-eight patients had fatty infiltration of the pancreas; these patients were considered as Group 1. Forty-two patients were considered as Group 2. Different fat distribution patterns were observed in Group 2, ranging from focal fatty replacement of the head to diffuse fatty infiltration of the entire pancreas (Fig. 1).

There was a moderate and significant negative correlation between the number of the CT attenuation of the pancreas and the BMI (r=-0.345, p=0.0001). The correlation between the number of the CT attenuation of the pancreas and the visceral fat area was substantial (r=-0.552, p=0.0001). The difference in correlations was significant (p<0.0025) (Figs. 2, 3).

There was a significant difference between the visually evaluated groups composed of different patterns of the fatty infiltration in terms of visceral fat area and the BMI (p=0.0001, p=0.008, respectively). A difference existed between Group 0 and 1 (p=0.0001) or Group 0 and 2 (p=0.0001) in terms of visceral fat area. The difference existed only between the Group 0 and Group 2 in terms of BMI (p=0.003) (Table 2).

Table 1. Patients Characteristics

<table>
<thead>
<tr>
<th>Groups</th>
<th>n (%)</th>
<th>Age (y)</th>
<th>BMI (kg/m²)</th>
<th>Visceral fat area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>46</td>
<td>52.24±14.49</td>
<td>28.89±5.65</td>
<td>153.35±72.28</td>
</tr>
<tr>
<td>Male</td>
<td>72</td>
<td>54.27±14.41</td>
<td>26.96±3.32</td>
<td>178.99±74.65</td>
</tr>
</tbody>
</table>

Note-Data are expressed as mean ± SD
BMI: Body Mass Index

Table 2. Relationship between the groups of the fatty infiltration of the pancreas and visceral fat area or BMI

<table>
<thead>
<tr>
<th>Groups</th>
<th>n (%)</th>
<th>Mean±SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visceral fat area (cm²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>70 (59.3%)</td>
<td>139.72-67.60</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>23 (19.5%)</td>
<td>207.52-56.90</td>
<td>0.0001</td>
</tr>
<tr>
<td>2</td>
<td>25 (21.2%)</td>
<td>215.54-69.07</td>
<td>0.0001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>70 (59.3%)</td>
<td>26.54-5.33</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>23 (19.5%)</td>
<td>27.46-2.92</td>
<td>0.394</td>
</tr>
<tr>
<td>2</td>
<td>25 (21.2%)</td>
<td>30.19-5.22</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Discussion

The pancreas is both an endocrine as well as an exocrine organ, where the exocrine portion of the pancreas accounts for about 80% of the total glandular volume. It consists of at least two different cells: acinar cells, which secrete primarily digestive enzymes, and ductal cells, which mainly secrete fluids and electrolytes. The endocrine system consists of the islets of Langerhans, containing several types of cells scattered within the exocrine tissue [3, 7, 8, 12].

Fat replacement of the exocrine pancreas (also known as fatty infiltration or lipomatosis) is known to occur, but the pathogenesis is not well-established. Most of the small amounts of the fat deposits have no major clinical significance. However, an extreme degree of fat replacement of the pancreas may be associated with a significant depression of pancreatic function. The replacement of pancreatic acini by adipose tissue may lead to exocrine pancreatic insufficiency, with resulting maldigestion of nutrients and a clinical picture of chronic diarrhea, steatorrhea, and weight loss without abdominal pain or diabetes. Massive fatty replacement has been described in the entity of lipomatous pseudohypertrophy of the pancreas. Interestingly, pancreatic islet cells are resistant to fatty infiltration [1-3, 7-10, 12].

Uneven fatty infiltration may be caused by differences in the histological characteristics between the two embryological pancreatic buds. The pancreas forms from two separate buds: the dorsal and the ventral buds of endodermal cells arise from the foregut. Microscopically, the embryological dorsal pancreas can be differentiated from the embryological ventral pancreas by less compact, loose lobules of pancreatic parenchyma with a larger amount of intralobular adipose tissue compared with the embryological ventral pancreas [3, 8]. Matsumoto et al. [8] have showed that the posterior aspect of the head of the pancreas and the area around the common bile duct tended to be spared.

No single etiology has been established for fat replacement of the pancreas; however, several predisposing factors have been suggested. These include the following: age, obesity, diabetes mellitus, chronic pancreatitis, alcoholic hepatitis, steroid therapy. In humans, autopsy studies show that the amount of adipose tissue in the pancreas correlates positively with the age and body weight [1-4, 7-10, 12]. We found a correlation between the fatty infiltration of the pancreas and visceral fat area. The fatty infiltration of the pancreas has also been reported in patients with obstruction of the pancreatic duct due to intraductal calculus or a tumor [2, 3]. In the latter group, fatty infiltration is more intense upstream from the obstruction.

There are several methods for the assessment of pancreatic fat content: abdominal ultrasound, which reveals lipomatosis due to the increased parenchymal reflectivity; computed tomography (CT), which measures the tissue attenuation; and magnetic resonance imaging (MRI) [10]. However, ultrasound is not considered to be a sufficient quantitative tool for fat determination in the pancreas. Several MRI methods are capable of assessing lipids in tissue, but MRI is not widely available in many centers. The disadvantages of MRI include its high cost, the long duration of the scan, and its sensitivity to movement. There are only a few studies dealing with lipid quantification of the pancreas [6, 10].

Recent CT and magnetic resonance imaging (MRI) studies have shown a correlation between the pancreatic fat and obesity [2, 6, 8]. Kovanlikaya et al. [6] showed the correlation of BMI and pancreatic fat. BMI, which is the ratio of body weight in kilograms to height.
in square meters, is the adiposity index most commonly used in adults [15]. However, if only weight or BMI are measured, this is not diagnosed as visceral fat type [15, 16]. Although anthropometric measurements, such as waist-to-hip circumference ratio and sagittal abdominal diameter, are simple and useful indicators of visceral fat accumulation, these indexes are not always accurate [3, 16]. Evaluation of visceral fat has been conducted using waist-to-hip circumference ratio and several images using CT, MRI, or ultrasonography. Of these methods, evaluation using CT is the most useful and popular method [5, 16]. Several studies revealed that visceral fat areas from a single scan obtained at the level of the umbilicus (approximately the level of L4 and L5) were highly correlated with the total visceral fat volume [16]. In the present study, we found a significant negative correlation between the enhancement number of the pancreas and the visceral fat area. According to our results, we can say that visceral fat tissue is more effective than BMI in the fatty infiltration of the pancreas.

It has been reported that fatty replacement of the pancreas is reversible in obesity after weight reduction. The data from experimental animals indicate that the ectopic deposition of lipids in the pancreas is associated with destruction of islet cells and impaired insulin secretion. Mathur et al. [7] described the new entity as nonalcoholic fatty pancreatic disease in obese mice. They postulated that the fatty pancreas might be more prone to pancreatitis similar to the development of nonalcoholic steatohepatitis from nonalcoholic fatty liver disease. Increased pancreatic fat, and, in particular, free fatty acids, may play a role in the progression of nonalcoholic steatohepatitis to cancer [7].

The present study has some limitations. Even though lower HU numbers may not depend on the fatty infiltration of the pancreas, we assumed that they did. Since we measured the attenuation number of the pancreas on portal-phase abdomen CT images, individual contrast enhancement differences may have occurred.

In conclusion, the visceral fat tissue area has a stronger correlation than BMI in the fatty infiltration of the pancreas. The amount of visceral fat tissue area is a better indicator than BMI that a patient has fatty infiltration of the pancreas.

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Conflict of interest statement The authors declare that they have no conflict of interest to the publication of this article.

References