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ABDOMINAL IMAGING

ORIGINAL ARTICLE

Is visceral obesity associated with colorectal cancer? The first volumetric study using all CT slices

Sinan Akay
Murat Urkan
Uğurcan Balyemez
Mehmet Erşen
Mustafa Taşar

PURPOSE
We aimed to examine the possible relationship between abdominal adiposity parameters and the presence of colorectal cancer (CRC) and between these adiposity parameters and various histopathologic findings of the tumor.

METHODS
A total of 60 control subjects and 111 CRC patients, 63 with early-stage and 48 with advanced-stage disease, were enrolled. Medical data and abdominopelvic computed tomography (CT) examinations of each study group were retrospectively reviewed. Abdominal adiposity parameters, including visceral adipose tissue (VAT) volume, subcutaneous adipose tissue (SAT) volume, and total adipose tissue (TAT) volume, were calculated on all slices of the CT examinations with specialized software, and results for each study group were compared. Adiposity parameters were also compared with tumor histopathologic findings.

RESULTS
We found lower VAT and higher SAT volumes in advanced-stage CRC patients, compared with the early-stage group. However, this relationship was not statistically significant ($P = 0.721$ for VAT and $P = 0.432$ for SAT volumes). We detected significantly lower VAT and SAT volumes in the early-stage CRC group compared with the control group ($P = 0.014$ for both). There was no significant relationship between TAT volumes and the study groups ($P = 0.06$). No statistically significant relationship was detected between adipose tissue parameters and histopathologic features of the CRC group ($P > 0.05$).

CONCLUSION
We found statistically significant lower VAT and SAT volumes in patients with early-stage CRC compared with the control group. Volumetric adipose tissue measurements may be more accurate than area measurements and can easily be performed on abdominopelvic CT examination, which is the routine imaging modality for CRC patients.

Adipose tissue, which is a loose connective tissue formed by adipocytes, is anatomically distributed in different quantities throughout the body, and this distribution is dependent upon many factors, such as sex, age, race, ethnicity, genotype, diet, physical activity, hormone levels, and medications (1–4). Body fat tissue is traditionally assessed as two main compartments with different metabolic characteristics: subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). Although both of these adipose tissue types are important, particular attention has been given to VAT because of its association with various medical conditions (1).

The rates of obesity and cancer, two of the most important health problems worldwide, are increasing. Obesity is known to be associated with an increased risk of cardio-metabolic diseases, including type 2 diabetes mellitus (DM), cardiovascular disease, and metabolic syndrome (5, 6). Moreover, the relationship between obesity and several types of cancer, including breast, esophageal, colorectal, and renal cancer, has also been shown (7). Although the exact underlying mechanism remains unclear, VAT, which is largely distributed in the abdomen and has a higher hormonal and metabolic activity than SAT, may play a crucial role in this relationship (8).

From the Departments of Radiology (S.A. ✉ *akaysinan04@yahoo.com*, U.B., M.E., M.T.) and General Surgery (M.U.), University of Health Sciences, Gülhane Training and Research Hospital, Ankara, Turkey.

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Cancer cachexia is defined as a multifactorial syndrome characterized by continuing skeletal muscle mass loss, with or without fat mass loss (9). It is a debilitating state of involuntary weight loss complicating malignant diseases and cannot be fully reversed by conventional nutritional support. The syndrome leads to progressive functional impairment and may contribute significantly to mortality (9, 10).

Colorectal cancer (CRC) remains the fourth most common cancer in the United States (11) and is well known as an "obesity-related" cancer (12). In the 1990s, some studies reported that abdominal adiposity parameters other than the body mass index (BMI) showed a better association with the increased risk of CRC (13, 14). Other studies evaluated the relationship between CRC risk and visceral obesity by using direct fat area measurements, but the results were inconclusive (15, 16). Whereas a few studies showed a relationship between the risk of CRC and VAT accumulation, some reported no significant relationship and even showed opposing results (12).

Computed tomography (CT) is one of the most accurate radiologic methods for assessing abdominal adipose tissue, and it has the ability to directly measure visceral adiposity (17, 18). Such specific measurements have been suggested to be more useful than BMI (19). Area measurements or volumetric calculations obtained from one or two CT slices were used in most studies evaluating the visceral adipose tissue. However, the results obtained by only a few CT slices and derived from areal measurements vary, partly because of the differences in measuring techniques (20). Currently, in contrast to the old areal calculations from only one or two slices, these measurements can be more accurately conducted volumetrically by using specific computer programs.

In the present study, we aimed to investigate the possible relationship between the volumetric abdominal adiposity measurements and the presence of CRC and between these adiposity parameters and various histopathologic findings of the tumors.

Main points

- Body fat tissue is traditionally evaluated as two main compartments with different metabolic characteristics: subcutaneous adipose tissue and visceral adipose tissue. Those can be easily and accurately measured with CT using specialized software.
- We designed a volumetric study on all slices of the abdominopelvic CT examinations of the patients with colorectal cancer by using specialized software.
- Statistically nonsignificant but lower visceral and higher subcutaneous adipose tissue volumes were found in early-stage (stages 1–2) colorectal cancer patients compared with advanced-stage patients (stages 3–4).
- We detected statistically significant lower visceral and subcutaneous adipose tissue volumes in the early-stage colorectal cancer group compared with the control group.
- No statistically significant relationship was found between abdominal adipose tissue parameters and histopathologic features of the colorectal cancer.

Methods

Patient selection

Institutional Review Board approval was obtained for this retrospective study (decision/protocol number: 2012-KAEK-15/1548). The medical data and abdominopelvic CT examinations of consecutive patients with newly diagnosed CRC who were operated in our hospital and a control group similar in age and gender distributions between January 2014 and October 2017 were reviewed. In total, 163 CRC patients and their medical data were evaluated. Patients were excluded from the study if any of the following criteria applied: patients with recurrent CRC (n=2); patients who had previous surgery for any other abdominal cancer or a major surgery that could affect abdominal adipose tissue (n=3); patients who were given neoadjuvant chemotherapy (n=10) and those with adenomatous polyposis coli disease (n=2); patients with insufficient histopathology reports (n=19); patients with limited or palliative resections and those who had emergency surgery for tumor-related complications (n=4); and CT examinations performed in another center (n=12). Finally, 111 patients (79 males, 32 females) with histopathologically proven CRC who met the criteria were enrolled in the study. In all of the cases, the final histopathologic diagnosis was made by colonic resection. The patients were separated into early-stage (stages 1–2) and advanced-stage (stages 3–4) disease groups for more detailed evaluation and in order to understand the possible effects of advanced disease and cancer-related cachexia on abdominal adiposity parameters. The early-stage cancer group consisted of 63 patients (49 males, 14 females), while the advanced-stage cancer group consisted of 48 patients (30 males, 18 females).

The control group was selected consecutively from patients who underwent abdominopelvic CT examination due to reasons other than abdominal cancer in the same time period as the CRC patients. The main indications for CT examination were nonspecific abdominal pain, suspicion of acute abdomen (such as cholecystitis or acute appendicitis), or suspicion of ileus for the control group. The age and gender distributions of the control group were similar to those of the patient groups. Subjects with history of major abdominal surgery or those diagnosed with any abdominal cancer in the current CT were excluded from the control group. In total, 60 subjects (47 males and 13 females) were included in the control group, and the same abdominal adipose tissue measurements mentioned above were conducted on them as well.

CT protocol and analysis

All of the CT examinations were performed prior to surgical resection with 64- and 320-row detector systems belonging to the same brand (Aquilion, Toshiba Medical Systems). Enhanced CT images were acquired in the axial plane in the portal venous phase after using a standard oral agent (50 mL, 76% amidotrizoate meglumine, sodium amidotrizoate) and intravenous nonionic contrast agents (mean, 80 mL), and multiplanar reformatted images (sagittal and coronal) were created from the initial scan. The scanning parameters were as follows: tube current, 150–200 mAs; tube voltage, 120 kV; slice thickness, 0.5–3 mm; rotation time, 0.75 ms; total scan time, 12.8 s.

The abdominopelvic CT images of patients and controls were retrieved from the picture archiving and communication system of our hospital and analyzed with an FDA-approved software program (Vitrea 2 Vital v4.1.8.0, Vital Images, Inc.) which was successfully used in some previous studies (21, 22) for calculation of abdominal adipose tissue parameters. All CT images in the soft tissue window between the esophageal hiatus in the diaphragm and the level of symphysis pubis were used, and abdominal adipose tissue volumes were calculated by using the "organ selection tool" option of the specialized software (Fig. 1). Visceral adipose tissue is defined as the deep adipose tissue, including the mesenteric, subperito-

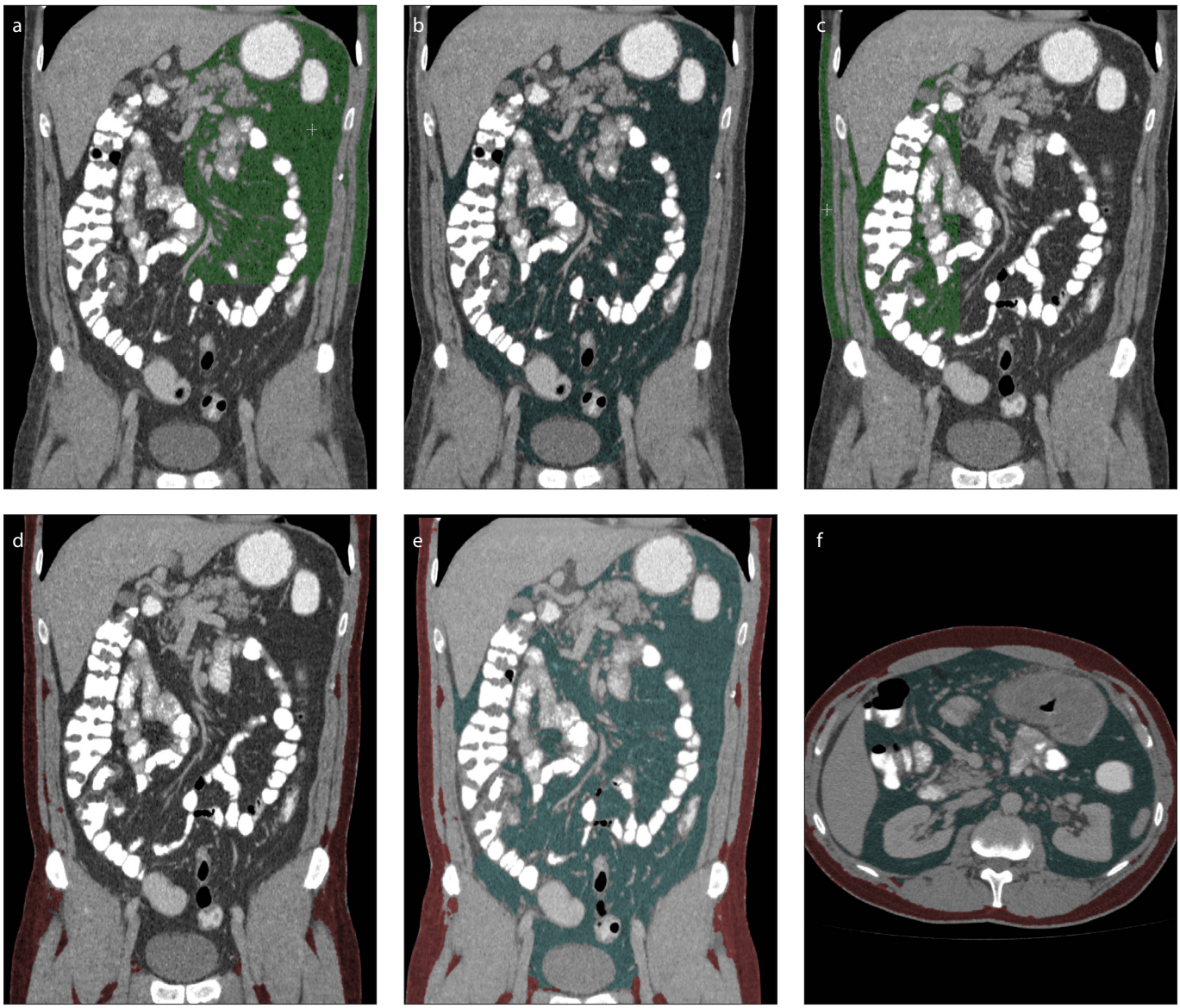

Figure 1. a–f. Abdominal adipose tissue measurements by using specialized software. Coronal **(a–e)** and axial **(f)** oral- and IV-contrasted abdominopelvic CT images. Image **(a)** shows marking of the visceral abdominal adipose tissue by using a plus sign (+) provided by the software. After the marking, similar density areas are determined, and image **(b)** is formed by the software. Image **(b)** demonstrates the final visceral adipose tissue mass *(dark green area)* which is selected by the software after manual editing by the researchers. Image **(c)** shows marking of the subcutaneous abdominal adipose tissue with a plus sign (+). After the marking, similar density areas are determined, and image **(d)** is formed by the software. Image **(d)** shows the final subcutaneous adipose tissue mass *(dark red area)*, which is selected by the software after manual editing by the researchers. Images **(e)** and **(f)** demonstrate the visceral *(dark green area)* and subcutaneous *(dark red area)* abdominal adipose tissue together. On image **(f)**, a transverse colon mass is readily seen.

neal, and retroperitoneal fat and excluding the paraspinal muscles and the vertebral column. Subcutaneous fat tissue is defined as the adipose tissue that is superficial to the abdominal wall musculature and the back muscles. After the region of interest selection of a representative area in the visceral adipose tissue at an appropriate level, the program derived an image showing the visceral adipose tissue in a different color. Two radiologists checked the images that were formed by the software for any mistakes, correcting and reforming the images when necessary in consensus. Images were manually edited in each section by using the "edit tool" in consensus to avoid including the non-fat tissue such as solid organs, intestines, vessels, and skeletal tissue. Then, using the subtracted 3D volume images created, the VAT volume was automatically calculated in milliliters by the program (Fig. 2). A similar process was applied for the SAT. The VAT and SAT volumes were summed up to measure the TAT volume. All measurements were taken by two radiologists in consensus. As all the images formed by the software were used for the measurements, estimation calculations, such as adding or multiplying by the pixel surface area, were not used, and thus adipose tissue volumes were calculated in real life.

Histopathologic analysis

The histopathologic data of the CRC patients retrieved from the medical archive of the hospital were evaluated for tumor location (right colon, transverse colon, left colon, sigmoid colon, rectosigmoid, and rectum), tumor size, disease stage, degree

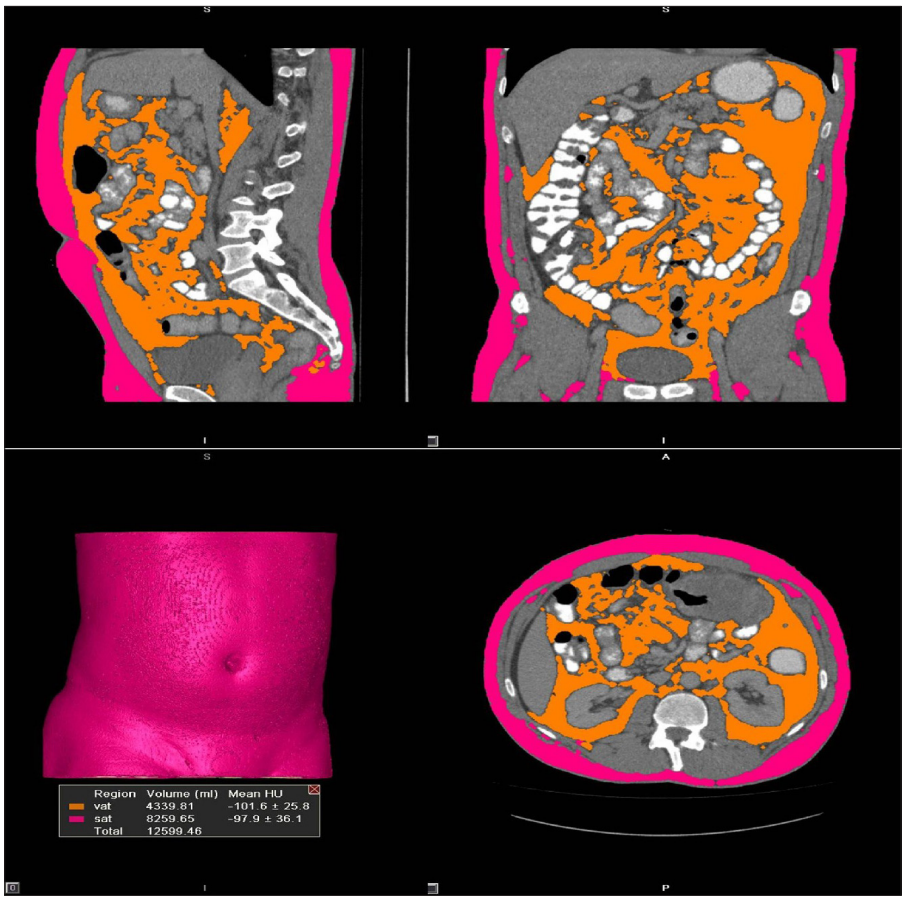

Figure 2. Abdominal adipose tissue measurements by using specialized software. The picture demonstrates the distribution of visceral *(orange)* and subcutaneous *(pink)* adipose tissues determined by the software in the sagittal, coronal, and axial projections. The lower left image is the volume-rendered image showing the visceral, subcutaneous, and total amount of abdominal adipose tissue in milliliters.

of histologic differentiation, muscularis propria and pericolonic fat tissue involvement, presence of mucin production in the tumor, lymphovascular invasion, perineural invasion, presence of lymph node and distant organ metastasis, and presence of DNA repair protein expression loss.

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences 20.0 software (SPSS 20.0 for Mac). Descriptive statistics of nominal variables were expressed with numbers and percentiles. Chi square test was performed to compare the independent nominal variables. Descriptive statistics of continuous variables were expressed as mean ± standard deviation (minimum–maximum) or median (minimum–maximum) according to normal or non-normal distribution of the variables. Kolmogorov-Smirnov test was used to assess the normality of distribution. Variance analysis was used to compare three or more normally distributed independent continuous samples. Independent sample t test was performed to compare two normally distributed independent continuous samples. Kruskal-Wallis test was used to compare three or more non-normally distributed independent continuous samples. The Mann-Whitney U test was used to compare two non-normally distributed independent continuous samples. Probability of $P < 0.05$ was accepted as statistically significant.

Results

A total of 171 cases were enrolled in this study. The early-stage (stages 1–2) and advanced-stage (stages 3–4) CRC patients and the control group were composed of 63, 48, and 60 cases, respectively. The patient group consisted of 79 (71%) males and 32 (29%) females. In the control group, 47 (78%) were males and 13 (22%) were females. The mean ages were 64.26±13.68 years, 62.08±13.69 years, and 64.26±10.32 years in the early-stage cancer, advanced-stage cancer, and control groups, respectively. No statistically significant difference was found between the three groups regarding age ($P = 0.116$) and gender ($P = 0.596$) distribution. The demographic features of the study groups are shown in Table 1.

The VAT, SAT, and TAT volumes were calculated using the specialized software. The abdominal adipose tissue parameters and their statistical relationship with the study groups are shown in Table 1.

The relationship between abdominal adipose tissue parameters and CRC was the main subject of this study. We evaluated possible relationships between adiposity parameters and the two groups with CRC. We found lower VAT volumes in the advanced-stage cancer group compared with the early-stage cancer group (3601 mL, range, 958–8367 mL vs. 3834 mL, range, 1280–10047 mL). However, this relationship was not statistically significant ($P = 0.721$). We detected higher SAT volumes in the advanced-stage cancer group compared with the early-stage cancer group, but they were again statistically nonsignificant ($P = 0.432$). No statistically significant relationship was found between TAT volumes and adiposity parameters in the two patient groups ($P = 0.954$). We suspect cancer-related cachexia may have affected the VAT and SAT volumes of the patients with advanced-stage disease. To overcome possible negative effects of this type upon abdominal adiposity parameter measurements, we excluded advanced-stage cancer patients. After this phase, we analyzed only two groups: early-stage cancer patients and the control group.

When we assessed the relationship between the early-stage CRC group and the control group, statistically significant lower VAT and SAT volumes were found in the early-stage cancer group ($P = 0.014$ for both). On the other hand, we did not detect any statistically significant relationships regarding TAT volumes in either the early-stage cancer group or the control group ($P = 0.06$). The detailed measurements and their relationship with the patient and control groups are shown in Table 1.

In the second phase of the study, we investigated the possible relationship between the abdominal adipose tissue parameters and the histopathologic findings of the tumors, such as tumor location, tumor size, disease stage, degree of histologic

Table 1. Demographic features and calculated abdominal adipose tissue parameters of the study groups

Demographic features and adipose tissue measurements	Early-stage cancer group (n= 63)	Advanced-stage cancer group (n= 48)	Control group (n= 60)	*P*	Post hoc comparisons *(P)*
Male, n (%)	49 (77.8)	30 (62.5)	47 (78.3)	0.116	
Female, n (%)	14 (22.2)	18 (37.5)	13 (21.7)		
Age (years), mean±SD (min–max)	64.26 ±13.68 (27–85)	62.08±13.69 (25–91)	64.26±10.32 (47–85)	0.596	
VAT (mL), median (min–max)	3834 (1280–10047)	3601 (958–8367)	4930 (772–10526)	0.01	Early stage-Advanced stage: 0.721 Early stage-Control group: 0.014 Advanced stage-Control group: 0.006
SAT (mL), median (min–max)	5534 (1146–15766)	5862.5 (2072–17488)	6810 (2563–17055)	0.042	Early stage-Advanced stage: 0.432 Early stage-Control group: 0.014 Advanced stage-Control group: 0.115
TAT (mL), median (min–max)	9670 (2455–23410)	9303 (3503–20589)	12318 (3335–24260)	0.001	Early stage-Advanced stage: 0.954 Early stage-Control group: 0.06 Advanced stage-Control group: 0.013

SD, standard deviation; VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue; TAT, total adipose tissue.

differentiation, muscularis propria and pericolonic fat tissue involvement, presence of mucin production by the tumor, lymphovascular invasion, perineural invasion, presence of lymph node and distant organ metastasis, and presence of DNA repair protein expression loss. The distribution of the histopathologic features of tumors is presented in Table 2.

We did not find any statistically significant relationship between the abdominal adipose tissue parameters and the histopathologic features of the CRC in our study groups ($P > 0.05$).

Discussion

In the current study, we used a specialized software program to measure the adipose tissue volumes located in different abdominal compartments. These measurements were performed involving the entire abdomen from the level of the esophageal hiatus to the symphysis pubis, and all the CT slices were used for volumetric calculations. Nemoto et al. (23) first reported this type of software and concluded that it was feasible for calculating visceral fat volumes in a reasonable time and was proved to have high accuracy. By using similar software, we avoided estimation calculations such as adding or multiplying by the pixel surface area. Thus, we were able to calculate real-life adipose tissue volumes, which would not be possible using the area measurements used in most previous studies (12, 24–28). By using this method, we were able to calculate even the thin subdiaphragmatic/perihepatic/perisplenic adipose tissue. To the best of our knowledge, this study is the first to utilize the real-life abdominal adipose tissue volumes created using all the CT slices rather than area measurements.

Currently, abdominopelvic CT is the routine imaging modality for most of the abdominal cancers, and it has been used worldwide for years. Being able to acquire high resolution images of the abdominal organs and the ability to evaluate bone tissues accurately at the same time in cancer patients are the main advantages. Additionally, CT is the preferred imaging modality evaluating the adipose and skeletal tissue due to its excellent resolution and it is a practical and precise method to directly quantify the body composition in both adult and pediatric populations (29, 30). There are many studies regarding the quantification of the body fat using CT, in the literature. However, in most of those studies, one or two CT slices representative of the whole adipose abdominal tissue were used for the measurements. Those studies advocate that a single slice from a specific abdominal level can represent whole VAT. However, they have some limitations such as small sample size and magnetic resonance imaging (MRI) use instead of CT (30, 31). Additionally, most studies using VAT area to approximate whole VAT volume used different abdominal levels for their measurements. In Japan, VAT at the level of the umbilicus is typically used in diagnostic criteria for metabolic syndrome (32). Mourtzakis et al. (30) used VAT measurements from L3 level on MRI images. Shen et al. (31) reported that the VAT area 10 cm above the L4-5 vertebral interspace in men and 5 cm above in women has greater power to detect VAT volume. Some other studies have used many different levels such as umbilicus, L3, and L3-4 vertebral space (12, 19, 29, 33–35). Due to these discrepancies regarding the VAT measurements in the literature, in the present study we chose volumetric method to measure the VAT volume utilizing a specialized program that uses all abdominopelvic CT slices.

We mainly investigated the possible relationship between some abdominal adipose tissue parameters and the prevalence of CRC. We found significantly lower VAT volumes in the early-stage CRC group compared with the control group. This inverse correlation was contrary to the general opinion and to most of the studies on this subject in the medical literature.

Many studies have been conducted on the relationship between abdominal adi-

Table 2. Detailed histopathologic features of the CRCs and their distribution in the patient group

Histopathologic features	Patient group (n=111)
Tumor location, n (%)	
Right colon	35 (31.6)
Transverse colon	2 (1.8)
Left colon	4 (3.6)
Sigmoid colon	28 (25.2)
Rectosigmoid	25 (22.5)
Rectum	17 (15.3)
Tumor size (mm), mean±SD	44.95±19.5
Differentiation grade, n (%)	
Well	4 (3.6)
Moderate	101 (91)
Poor	6 (5.4)
Disease stage, n (%)	
Stage 1	14 (7)
Stage 2	45 (22.4)
Stage 3	39 (19.4)
Stage 4	7 (3.5)
Missing	6 (3)
Muscularis propria invasion, n (%)	
No	0 (0)
Yes	111 (100)
Subserosal fat invasion, n (%)	
No	19 (17.1)
Yes	92 (82.9)
Pericolonic fat invasion, n (%)	
No	89 (80.2)
Yes	22 (19.8)
Lymphovascular invasion, n (%)	
No	63 (56.8)
Yes	47 (43.2)
Perineural invasion, n (%)	
No	89 (80.2)
Yes	16 (14.4)
Missing	6 (5.4)
Mucinous component, n (%)	
No	88 (79.3)
Yes	23 (20.7)
Lymph node metastasis, n (%)	
No	71 (64)
Yes	40 (36)
Distant metastasis, n (%)	
No	106 (95.5)
Yes	5 (4.5)
DNA repair protein expression loss, n (%)	
No	62 (55.9)
Yes	8 (7.2)
Missing	41 (36.9)

pose tissue parameters and some clinical and surgical features of CRC, including the prognosis, outcomes after colorectal surgery, and postoperative complications (11, 12, 25, 26, 34, 36). However, only a limited number of studies are directly related to the relationship between the adipose tissue parameters and the prevalence of CRC as in our study. Lee et al. (12) reported that the visceral fat area was positively associated with the prevalence of CRC in their study involving 398 postmenopausal women. They calculated the fat tissue by using areal measurements created from one CT slice at the level of L4–L5 interspace but could not determine the causality; nevertheless, they concluded that visceral adiposity could be associated with the risk of CRC. Nagata et al. (37) found that the risk of colorectal adenoma was significantly associated with visceral adipose tissue and the VAT-to-SAT ratio. Another study by Kang et al. (38) showed that visceral obesity was found to be an independent risk factor of colorectal adenoma. A recent study by Seo et al. (39) also showed that the visceral fat area was positively associated with the presence of colorectal adenoma, especially in men. Contrary to the general opinion in the medical literature, Choe et al. (27) showed that visceral obesity is not a risk factor for early CRC. Additionally, Erarslan et al. (40) reported in their 104-case study (54 cases with CRC and 50 controls) that VAT area measured from the L4 vertebra level did not differ between colorectal neoplasia patients and healthy controls. However, in all the abovementioned studies on visceral fat and colorectal neoplasms, adipose tissue calculations were conducted by areal measurements in contrast to our study. To the best of our knowledge, our current volumetric study is the only one in the medical literature advocating visceral obesity to be inversely correlated with the prevalence of CRC.

We also examined the possible relationship between the abdominal adipose tissue parameters and some histopathologic features of the CRC mentioned above. Only a limited number of studies have been conducted on the relationship between the adiposity parameters and the histopathologic features of CRC. Park et al. (25) reported that a higher ratio of visceral fat was associated with a decreased lymph node metastasis. A study by Jeong et al. (24) showed that obese patients tend to have smaller CRC

lesions than their non-obese counterparts. We did not find any statistically significant relationship between the abdominal adiposity parameters and histopathologic features of the tumors. As far as we know, this study is the first to investigate the possible relationship between the abdominal adipose tissue parameters and such a wide spectrum of histopathologic findings in any cancer.

Although which kind of obesity affects colorectal carcinogenesis is not clear and has been under-explored, insulin resistance, insulin-like growth factor-1, visceral fat tissue, biochemical markers such as adiponectin and leptin, and other biological factors such as inflammation, bile acids, and the microbiota may be the major culprits (11). VAT has been identified as a risk factor for CRC (13, 15) and colorectal adenoma (41) in some studies and was specified as a more accurate marker than waist circumference and BMI for increased CRC risk (14, 39, 42). Nevertheless, the association between VAT and CRC has been questioned (40). Colorectal neoplasia follows the "adenoma-carcinoma sequence" (43), which is characterized by progression from precancerous adenoma to carcinoma. Multiple factors, such as cell cycle, apoptosis, genetic instability, environmental factors, inflammatory cells, and dietary carcinogens, affect every step of this sequence (27, 44, 45). Additionally, the Wnt/β-catenin pathway, E-cadherin and α-catenin, the adenomatosis polyposis coli gene, BRAF, NRAS, VEGF genes, and stem cells play important roles in colorectal carcinogenesis (46). Choe et al. (27) assessed the effects of visceral obesity on the "normal to cancer" and "adenoma to cancer" progressions in their study. They showed that visceral obesity might affect the "normal to adenoma sequence" but not the "adenoma to carcinoma sequence." The results of assessing this relationship are mostly inconclusive. Different studies have shown positive effects, negative effects, and no association. The complex pathophysiology of the relationship between abdominal adipose tissue and CRC, a small sample size, the effect of weight loss due to tumor prior to abdominal fat tissue measurements, the confounding effect of unequal clinical characteristics of the study population, and discrepancies regarding adipose tissue measurement techniques may be factors that contributed to the inconsistent and unexpected results (12). The lower VAT and higher SAT volumes, which were found in CRC patients in our study, are novel findings in literature. However, we could not find any causality in the inverse correlation except the different measurement method. This complex situation may also be due to reverse causation, selection bias, or other forms of bias, rather than true biological association. However, we enrolled 63 histopathologically proven early-stage and 48 advanced-stage CRC patients, as well as an age-, gender-, and number-matched control group to overcome selection bias. These numbers represent one of the largest sample sizes of similar studies. FDA-approved specialized software and a manual editing system were used for abdominal adipose tissue measurements to prevent miscalculations. Unlike previous studies that used area abdominal adipose tissue calculations from limited CT slices, we formed a measurement method nearest to real life. Volumetric adipose tissue measurement using all the CT slices may be more accurate than using area measurements. The novel findings of our study may be a step toward further large-scale studies regarding this subject, which is open to new challenges.

Our study has several limitations. The retrospective design of the study is the most important one. Not knowing how long the patients have had CRC before the initial diagnosis is a major limitation because, in this time interval, the abdominal adipose tissue quantities could have been affected. To overcome this disadvantage, we excluded advanced-stage CRC patients from main phase of the study. We did not pay attention to endocrine problems, such as DM, and this condition might have also affected the amount of adipose tissue. Not knowing the weight of the cases in the patient and control groups can be counted as a limitation that may have affected the statistical results. To overcome this limitation, we selected the control group from the consecutive age- and sex-matched patients who applied to our radiology department.

In conclusion, this study investigated the possible relationship between abdominal adipose tissue quantities and the prevalence and histopathologic features of CRC. We performed a volumetric study by using specialized software and aimed to overcome possible disadvantages of the area measurement, which could not reflect the adipose tissue of the entire abdomen. We did not find any statistically significant relationship between abdominal adipose tissue parameters and histopathologic features of CRC. Additionally, lower VAT and SAT volumes were detected in early-stage CRC patients compared with the control group. We could not find any prominent causality for this result other than the different measurement method. We think that this different measurement method may have caused the unusual result of our study, which was contrary to what is generally known in the literature. The volumetric adipose tissue measurements may be more accurate than area measurements, and they can be readily done on abdominopelvic CT examination, which is the routine imaging modality for CRC patients. However, further studies must be conducted on the subject.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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