The contribution of CT examination in abdominal fat assessment

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Introduction

Fat quantitative assessment is important for the diagnosis, treatment and prognosis of diseases related to obesity. The standard obesity evaluation methods such as weight and height ratio, waist and hip circumference ratio, and subcutaneous fat thickness by caliper, have a weak point that they do not measure body fat quantitatively.

Computed tomography (CT) DICOM image format has for each pixel tags with multiple variables, including ones related to attenuation coefficients. Based on its linear transformation a derivate unit is calculated- the Hounsfield unit (HU) providing excellent tissue characterization.

CT's high spatial resolution and fast acquisition time pushed it as a gold standard in abdominal fat measurements and in abdominal compartments segmentation. Multiple techniques have been used but there is no definitive answer regarding the HU value interval or the technique to be used to measure abdominal fat on CT images.

1st Study: (re)Defining fat Hounsfield Unit reference interval

Objectives:

- To apply the indirect Hoffmann method in establishing fat HU reference intervals and evaluate its comparison with experimental studies
- To establish reference intervals (RI) for abdominal fat visceral and subcutaneous compartments

Material and methods: 50 patients (M:F 1.27) who underwent routine abdominal CT examination were included in the study. 4 slices were selected at standard anatomical location: left adrenal gland, superior mesenteric artery ostia, umbilicus and antero-superior iliac spine. 10 subcutaneous and 10 visceral fat HU samples were collected using the circular region of interest (ROI) tool. The outliers were removed using Chauvenet's criteria and using visual analysis the linear part of cumulative frequencies plot of average HU values was selected. Using the least-squares analysis the best-fitting linear regression equation was determined ($y=\alpha x+\beta$)) and the RI's were calculated for x=2.5% and 97.5%.

Results: Subcutaneous fat has higher HU values than visceral fat, with a difference of 4.5 UH, $p < 0.0001$. There are small but significant differences between sexes for visceral fat HU but not for subcutaneous

fat. The computed reference intervals are (-90:-124) HU for subcutaneous fat and (-83:-123) HU for visceral fat.

Conclusions: The method for the indirect determination of reference intervals from existing datasets has proven to be consistent and reproducible, producing RIs that were comparable to the ones reported in experimental studies. Software tools relying on HU values for fat evaluation should keep note of the difference of HU values.

2nd Study: Evaluating abdominal fat compartments using cross-sectional CT images

Objectives:

- To use non-proprietary software and technologies to evaluate abdominal fat compartments
- Assess the impact of using different reference intervals on abdominal fat compartments evaluation
- Evaluate the link between clinical parameters and abdominal fat compartments
- To draft proposals to improve the abdominal CT reporting of obese patients

Material and methods: a convenience sample of 252 patients (M:F= 1,13), aged 24 to 92, who underwent routine abdominal CT examination was included. For each patient reconstruction was done using a double oblique plane including the umbilicus and L4/L4 intervertebral space. The resulting DICOM file was processed using a MATLAB script which generated a new file where the pixels corresponding to HU values inside a certain threshold were set as 1 and those outside of threshold were set as 0. A semiautomated method was developed further, using ImageJ software, to segment and quantify the abdominal fat for each slice.

Results: The method provided excellent reproducibility, with intra and interobserver correlation coefficient of 0,9993 and 0,9996. As expected, patients with abdominal obesity have higher visceral fat percentage, on average with 41 cm^2 (6%). There is a tendency of visceral fat area to increase with age in males with abdominal obesity (R^2=0,94) and females without abdominal obesity R^2=0,57. There is a positive correlation between abdominal circumference and the areas of both visceral and subcutaneous fat, which is present regardless of the fat HU threshold. Using a mixed threshold with distinct reference interval for visceral and subcutaneous fat the correlation coefficient is 0,49. In a multilinear regression equation with visceral fat area (VFA) as dependent variable abdominal circumference has a significant positive impact while age has a weak positive correlation.

Conclusions: A robust method for non-invasive evaluation of abdominal fat compartments was successfully implemented. The method provides good correlation between imaging and clinical indicators without relying on proprietary software and being vendor independent. To help the reporting radiologist we are recommending reference intervals for both VFA as area and VFA as percentage of total fat area.

3rd Study: The link between clinical laboratory data and abdominal fat indicators determined on CT images

Objective: to evaluate abdominal fat compartments (visceral and subcutaneous) correlation with laboratory tests (glycaemia, total cholesterol and triglycerides).

Material and methods: 170 patients (M:F=1,1 with average age 62.5 years) who underwent abdominal CT examination with available laboratory data of interest. Abdominal fat segmentation was performed using fat HU threshold as established in 1st study and with the methods evaluated in 2nd study

Results: We found a weak but significant correlation (r=0.2686) between triglycerides and visceral fat, while the other parameters had non-significant correlations (p>0.05). Hyperglycemia was found to be associated (p=0.04) with visceral fat area above 70 cm^2 and with total fat area above 130 cm^2. Hypercholesterolemia was significantly associated with a total abdominal fat area above 200 cm^2 but with a weak (r=0.2137) but significant positive correlation.

Conclusions: CT abdominal fat indicators have a weak, positive correlation with triglyceride values and an association with high values of blood sugar and cholesterol.

Thesis Originality and Innovative Contributions

Thesis originality is given by two approaches:

The approach on measuring fat compartments Hounsfield Unit

- It's the first method using an indirect a posteriori technique to establish a reference interval for fat Hounsfield unit values
- It's one of the few studies trying to establish different HU values not just for all abdominal fat but for its compartments (visceral and subcutaneous)

The approach on using sectional imaging to evaluate abdominal fat compartments

- To our knowledge, it's the first paper using multiple anatomical landmarks to create slices, allowing for excellent reproducibility
- The paper uses commercial, free and in-house developed software to distinguish abdominal fat compartments, independent of the image window used for DICOM file evaluation

Keywords:

Computed tomography, Hounsfield unit, abdominal fat, visceral fat, subcutaneous fat