Chapter 4

CT Measurement of Visceral Fat

After completing this chapter, the learner should be able to:

- Discuss the health risks associated with excess visceral fat
- Explain how visceral fat builds up and how to minimize it
- Implement CT protocols for visceral fat volume measurement

INTRODUCTION

It is well-established that the distribution and volume of fat, especially visceral fat, is a predictor of future health. Viscera are the internal organs of the body, specifically those within the chest and abdomen. Normal amounts of visceral fat accumulate deep within the abdomen in the spaces between organs like the liver, pancreas and kidneys and serve to pad and protect the organs.

VISCERAL FAT: THE GOOD, THE BAD, AND THE UGLY

Why is Visceral Fat a Risk to Health?

Visceral fat protects the vital organs, but what happens when there is a build-up of visceral fat?

People who have protruding bellies with excessive subcutaneous fat are likely to carry excess visceral fat, too (**Figure 1**). Excess visceral fat, also called intra-abdominal fat, increases health risks from many life-threatening diseases like cancer, stroke, diabetes, and coronary artery disease[1,2] and impacts lifestyle by increasing the risk of dementia, depression, arthritis, sexual dysfunction, and sleep disorders. Storing excess fat around the organs increases the production of pro-inflammatory substances that interfere with hormones which control appetite, weight, mood, and brain function.[1]

Figure 1. Illustration of where visceral fat. Is stored.
Courtesy of Sandra Cohen-Rose and Colin Rose available at: flickr.com

Men tend to carry more visceral fat than women. For males, visceral fat begins accumulating in adolescence and early adulthood. For females, visceral fat tends to start building post-menopause, perhaps due to decreased levels of estrogen.[2] Native Americans and Hispanics are more likely to accumulate visceral fat than other ethnic groups.[3]

Why Visceral Fat Builds Up

While a normal level of visceral fat is necessary, why does excess visceral fat accumulate to an unhealthy proportion? First, we need understand how what we eat impacts our blood glucose levels.

Blood glucose levels increase after eating, which in turn stimulates the pancreas to release insulin. Insulin has an effect on a number of cells, including red blood cells, muscle, and fat cells. In response to the release of insulin, these cells absorb glucose from the blood, resulting in a decrease of high blood glucose levels to within the normal range.[4]

Blood glucose energizes the brain, tissue, and muscles. Once sufficient blood sugar is utilized, the balance is stored as fat[1], which provides energy, absorbs nutrients, and maintains body temperature. Consuming highly refined and processed carbohydrates, especially in excess, can lead to insulin resistance, a condition where the pancreas produces insulin but the body is unable to use it effectively resulting in a build-up of glucose in the blood. Under normal conditions, blood glucose is absorbed by cells for energy, but an excess of blood glucose over a period of time will develop into prediabetes or full-blown Type 2 diabetes[1].

High insulin levels create a vicious circle of increased appetite that in turn leads to continued overeating and weight gain.[1] The more often and longer that insulin levels remain high, the more likely that excess body fat will accumulate.[1, 5] Just as for obese individuals, excess visceral fat has been associated with insulin resistance and metabolic syndrome in non-obese people.[6]

Methods to Reduce Visceral Fat

Healthy eating, exercising, and maintaining proper sleep habits are the best ways to reduce excess visceral fat. Controlling portion sizes and decreasing saturated fat intake will decrease the amount of all types of fat. The good news is that visceral fat is easier to lose than subcutaneous fat.[2] Exercise, especially cardiovascular activities, is effective for reducing the volume of visceral fat.

Whole grains, fruits, vegetables, and lean proteins should replace processed carbohydrates and sugary foods. High fiber foods are more filling and therefore decrease overeating. Healthy fats like avocados, nuts, and olives are also good diet choices. Aerobic activity, strength training, and targeted abdominal toning exercises will also decrease subcutaneous and visceral fat. [7]

Methods for Measuring Visceral Fat

Measuring Body Mass Index (BMI), which is based on height and weight, has historically been the standard for measuring body fat. Several studies, however, have reported that measuring BMI does not accurately measure obesity but instead serves as a general and potentially misleading indicator of health status. BMI has not been found to be a predictor of life expectancy, and being thin or having a low BMI does not protect against premature death. Rather, a direct measure of body fat is the most accurate way to determine health and risk for future health events. [8]

Waist-to-hip ratio

There are several methods for measuring visceral fat. The easiest method is by tape measure. Circumference measurements of the waist and hip are taken to calculate waist-to-hip ratio. The waist measurement is taken at the level of the umbilicus, and the hip measurement at the greatest protrusion of the buttocks. The waist measurement is then divided by the hip measurement to obtain the waist-to-hip ratio. For men, the ratio should not be > 1.0 and for women > 0.85. This simple technique is an estimate and not as accurate as other means for measuring visceral fat. [9]

Determining *where* fat is carried, however, is a predictor of health, and measuring waist-to-hip ratio easily demonstrates if a person is apple-shaped, where weight is carried around the midsection, or “pear-shaped,” with weight carried around the hips and a narrower waist. People who carry weight around their abdomens are at higher risk for death and disease than those who carry weight around the hips and thighs. [8]

Bioelectrical impedance analysis

Bioelectrical impedance a convenient, inexpensive, and portable means for estimating visceral fat and is used at home and in the clinical setting. This device analyzes the electrical resistance of tissue in the body by using a small, harmless electrical current. Bioelectric impedance measurements are calculated as an electrical signal easily passes through lean tissue and encounters resistance when passing through fat. Bioelectric impedance devices emit no radiation, are safe, and reasonably accurate for estimating body composition.

DEXA

The use of dual-energy X-ray absorptiometry (DEXA) is a relatively inexpensive and accurate means for quantifying visceral fat. A 2012 study by Kaul et al compared DEXA to CT for visceral fat measurement. Their algorithm for measurement of total abdominal thickness was based on X-ray attenuation and the width of the layer of subcutaneous fat in the abdominal area. The volume of visceral fat was determined by subtracting subcutaneous fat from the total fat of the abdomen. The authors concluded that DEXA can precisely measure abdominal visceral fat both men and women.

In addition to the lower cost and greater availability of DEXA units, radiation exposure is significantly less than that of a CT visceral fat measurement study.[6]

Ultrasound and MRI

Calculating visceral fat on ultrasound is simple, fast, and relatively inexpensive. Although ultrasound is relatively accessible for patients, the accuracy and reproducibility of ultrasound is somewhat poor.[10]

MRI more accurately calculates the volume of visceral fat but is very expensive and less accessible than ultrasound and CT. Some studies have shown that compared with CT, MRI may overestimate the amount of both subcutaneous and visceral fat.[9]

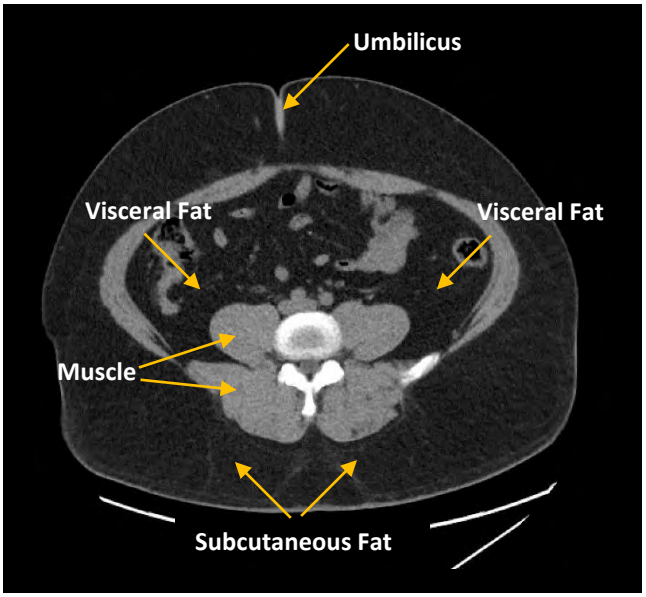

Figure 2. Axial image of visceral fat.

Computed tomography

The most accurate and relatively accessible method for measuring visceral fat volume is with CT (**Figure 2**).[10] Performing CT solely for calculating visceral fat volume is generally limited to research purposes as CT scanning exposes the patient to ionizing radiation. For this reason, visceral fat measurement is often acquired in conjunction with a diagnostic CT to assess irregularities in the abdomen. Preventative medical practices may also request visceral fat measurement when ordering a whole body CT screening exam.

VISCERAL FAT MEASUREMENT PROTOCOL

Visceral fat calculations are obtained at the level of the umbilicus, so only a small area of *z*-axis coverage is required superior and inferior to the umbilicus. The scan field of view must include all subcutaneous fat for accurate measurements. Low dose protocols using iterative reconstruction are preferred to decrease radiation exposure. For visceral fat CT, 1cm image thickness and intervals are adequate and further reduce radiation dose as compared to the 5mm or 2.5mm sections routinely acquired in abdominal CT scanning.

> *The scan field of view must include all subcutaneous fat for accurate measurements.*

Images are sent to a workstation to calculate the total amount of fat and visceral fat at the level of the umbilicus. Minimum and maximum HUs for fat are -30 and -190, which correlate with the region of interest (ROI) numbers for fat (**Table 1**). Threshold values for fat are set to subtract all structures like muscle, solid organs, and intestines so that the image visualizes only subcutaneous and visceral fat (**Figure 3**).

ROI area measurements are first acquired for the total volume fat and again for only visceral fat. Multiple studies have shown that CT ROI area measurements that exceed 110cm^2 in women and 131cm^2 in men are associated with increased risk of cardiovascular disease.[10]

Matter	Density (HU)
Air	-1000
Lung parenchyma	-850 to -910
Fat	-30 to -190
Water	0
White matter	20 - 30
Kidney	20 - 40
Spleen	35 - 55
Grey matter	37- 45
Blood	45 - 65
Liver	45 - 65
Hematoma	40 - 90
Bone	700 - 3000

Table 1. HUs to various tissues. Note: The number of HUs may vary depending on the source.

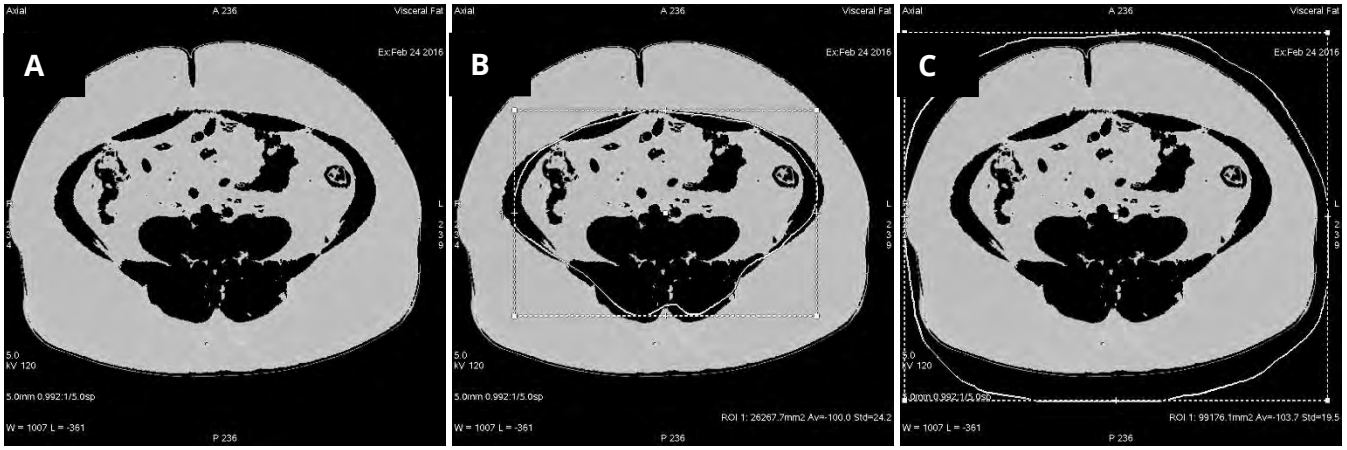

Figure 3 (A)Threshold applied to subtract non-fat structures; (B) visceral fat area measurement in mm^2; (C) total fat area measurement in mm^2 (both subcutaneous and visceral fat).

SUMMARY

Reducing the amount of excess visceral fat is essential for good health, and the use of CT has been found to reliably and accurately calculate the volume of visceral fat to aid patients in establishing a course of healthy eating and lifestyle.

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