Visceral Fat Evaluation and Clinical Significance

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Introduction

Obesity is widely recognized as America's most serious public health problem following a Center for Disease Control (CDC) report that 78 million adults (37.5%) and 12.5 million children (17%) are obese.[1] For the first time in recorded history, obesity threatens to reduce life expectancy from both chronic and acute diseases including cardiovascular disease, stroke, dyslipidemia, cancer, hypertension, and diabetes. The secular trend of increasing obesity across all age groups has led to an increased focus on the diagnosis and management of obesity and obesity-related health risks (see Figure 1).[1]

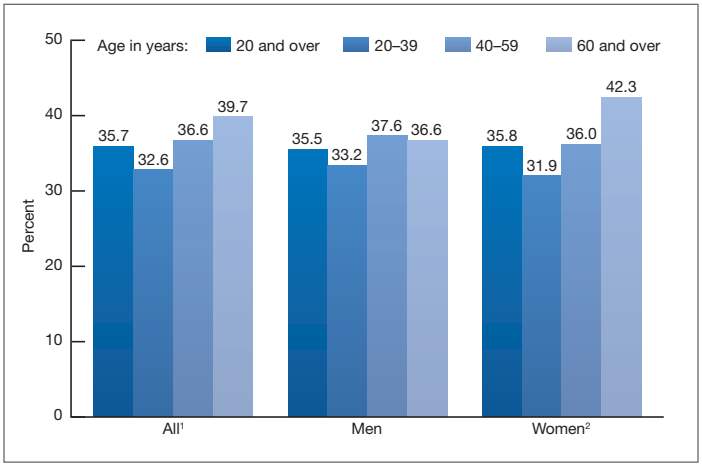

Figure 1. Prevalence of obesity among adults aged 20 and over, by sex and age: United States, 2009-2010

The explosion of type 2 diabetes over the past decade is perhaps the most serious consequence of the current obesity epidemic. Nearly 2 million adult Americans were diagnosed with diabetes in 2010 alone, and the CDC estimates that 79 million Americans are pre-diabetic. Diabetes is the leading cause of kidney disease, a major cause of heart disease and stroke and the seventh leading cause of death in the United States. The financial burden of the disease is staggering; in 2007 alone total expenditures amounted to $174 billion including medical costs and indirect costs such as disability, loss of work, and premature death from diabetes.[2]

There is mounting evidence that the distribution and type of excess fat may be an important prognostic indicator for disease risk. Unlike subcutaneous fat whose main function is energy storage, visceral fat cells are metabolically active and impact a wide variety of clinical risk factors including fasting glucose levels, serum triglycerides, and cholesterol.[3, 4]

Visceral fat occurs within the envelope formed by the abdominal muscles, principally within the greater and lesser omentum that connects the abdominal organs, and in mesenteric fat. A small amount is also found retroperitoneally.[5] Visceral fat is more dangerous than subcutaneous fat because visceral fat cells release proteins that contribute to inflammation, atherosclerosis, dyslipidemia, and hypertension. Visceral fat is associated with metabolic risk factors and all-cause mortality in men[6], and is therefore considered a pathogenic fat depot.[7]

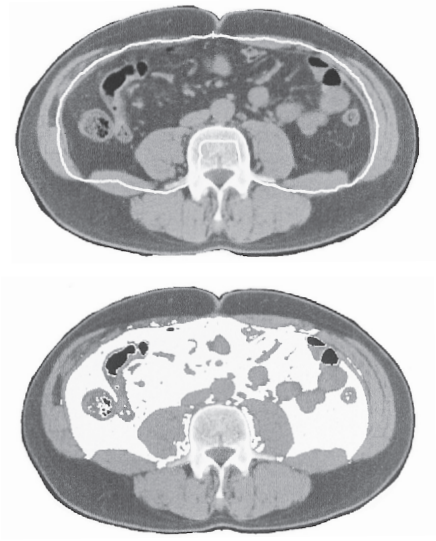

Figure 2. Computed tomography image of the abdomen at the level of the fourth lumbar vertebrae with visceral cavity outlined in white (top) and visceral fat filled in (bottom).[8]

Methodology

Hologic scientists have recently developed and patented[9] a method for measuring visceral fat from a DXA whole body scan that is highly correlated and linearly related to visceral fat measurements by computed tomography.[10] This development allows clinicians and researchers to classify subjects with excess visceral fat, thereby identifying the population with the greatest obesity related health risks. Diet, exercise, surgical, and pharmaceutical interventions can now be targeted toward high risk individuals to maximize health benefits.

The main breakthrough in using DXA for the measurement of visceral fat was the recognition that the subcutaneous fat ring, inner abdominal muscle wall, and visceral cavity are all recognizable anatomical features on Hologic Discovery high resolution DXA whole body images. Automated software algorithms identify these anatomical features at the level of fourth lumbar vertebrae. Using appropriate modeling, the amount of subcutaneous fat in the abdominal region can be estimated from the subcutaneous fat on each side of the abdominal cavity. This estimate of subcutaneous fat is subtracted from the total abdominal fat in the abdominal region to yield visceral fat.

DXA visceral fat area measurements obtained with this method were highly correlated (r=0.93) and linearly related to visceral fat area measured by computed tomography in a study of 272 black and white women.[10] The low prediction error (SEE=16 g/cm^2) and strong functional relationship reported in this study indicates that DXA and computed tomography measurements of visceral fat are substantially equivalent. Subsequently the DXA visceral fat application received FDA clearance, an achievement with several practical and technical advantages since DXA exams are widely available, less costly, and deliver a small fraction of the radiation dose compared with computed tomography. Furthermore existing whole body exams, e.g. exams utilized in clinical medicine and in research studies, can be reanalyzed with the new visceral fat application as it is 100% backward compatible with all modern Hologic fan beam technology.

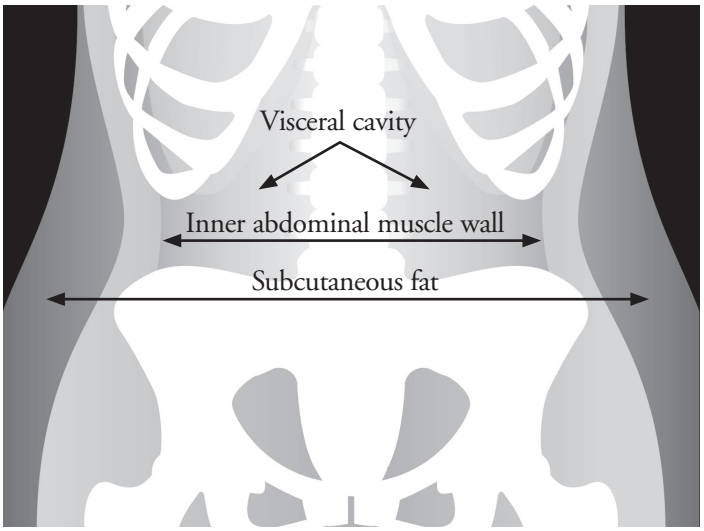

Figure 3. Stylized representation of DXA projected image showing anatomical features including subcutaneous fat, abdominal wall, and visceral cavity.

Clinical Management and Interpretation

It is important to recognize that even subjects who are normal weight and have a Body Mass Index (BMI) < 25 can have a significant accumulation of visceral fat, increasing their risk for cardiovascular disease, diabetes, and other obesity related health risks. Likewise, some overweight or obese patients may have relatively low levels of visceral fat, normal metabolic profiles, and few or no additional risk factors. A DXA visceral fat measurement may distinguish apparently normal weight subjects with high visceral fat levels and high disease risk from metabolically normal subjects with BMI's in the overweight or obese category.

Virtually all visceral fat studies in the literature report visceral fat in units of area (cm^2); only Hologic Discovery DXA scanners report visceral fat in its native area format.

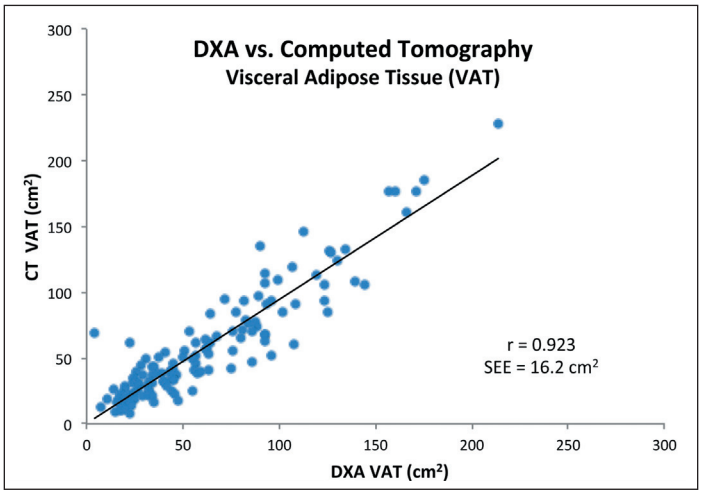

Figure 4. Correlation between visceral fat area measured by computed tomography (CT) and DXA.

Cross-sectional studies have suggested that visceral fat levels exceeding 100-110 cm^2 adversely affects the metabolic profile in women.[11] Pickhardt et al found that a visceral fat area threshold of 70 cm^2 yielded a sensitivity, specificity, and accuracy of 83.7%, 80.0%, and 81.3%, respectively, for metabolic syndrome in women. Visceral fat area performance was somewhat lower in men using a 125 cm^2 threshold.[12]

Nicklas found that a visceral fat area of 106 cm^2 was associated with an elevated risk of metabolic coronary heart disease (CHD) risk factors and a visceral fat area of 163 cm^2 was associated with a markedly increased risk in women. The study concluded that "these values may prove useful for defining visceral obesity and for identifying women most likely to benefit from preventative interventions". [13]

Visceral Fat Diagnostic Thresholds

Diagnostic thresholds for visceral fat are becoming more firmly established as further clinical and research experience is gained. Data from population based studies such as NHANES will supplement the knowledge base with reference values that will provide the analytical framework for interpreting DXA visceral fat measurements. In the interim the available literature supports visceral fat thresholds of 100 cm^2 for increased risk and 160 cm^2 for high risk.

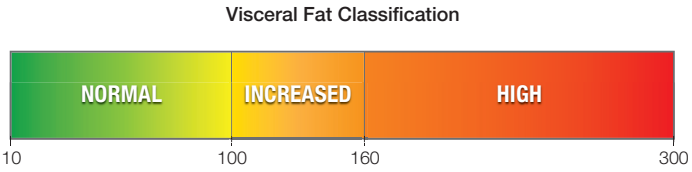

Figure 5. Visceral fat thresholds associated with metabolic risk factors for coronary heart disease.[12, 13]

Summary and Conclusion

Recent government health statistics reveal that obesity has exploded to epidemic levels. The management of clinical obesity and its related health risks is a vexing clinical problem. The reliance on antiquated measurements such as BMI, scale weight, and waist circumference further compounds the problem, as anthropomorphic measures often do not adequately assess obesity related risks. The end result is that commonly used clinical measures of obesity misclassify individuals in terms of visceral adipose tissue and disease risk.[14]

Improvements to traditional measures of obesity are needed, and these refinements must be widely available and cost effective. It has been previously argued[15] that DXA Fat Mass Index (FMI; Fat Mass/Ht^2) measurements are superior to BMI for obesity classification because FMI is a gender specific measurement of excess fat, whereas BMI is a measure of excess weight. Likewise, DXA measurements of visceral fat more accurately assess health risks compared with non-specific measures because visceral fat is a primary pathogenic fat depot.

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