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Imaging Techniques for Nutritional Assessment

Joohyun Shim, Hoon Hur

Department of Surgery, Ajou University School of Medicine, Suwon, Korea

Accurate measurement of body composition between lean and adipose tissue mass and distribution of lipid burden may be important in the care of nutritional problems in patients observed in clinical practice and the measurement of outcomes in clinical research. In this review, we discuss the most accurate imaging methods for use as clinical tools in measurement of body composition and distribution. Dual-energy x-ray absorptiometry (DXA) is a non-invasive technique for assessment of body composition, and the radiation exposure is relatively minimal. However, measurements are influenced by thickness of tissue and lean tissue hydration. Computed tomography (CT) is a gold-standard imaging method for body composition analysis at the tissue-organ level, however the radiation generated by the CT scan is relatively high, thus it should not be considered for a measurement, which can be repeated frequently. Magnetic resonance imaging (MRI) has been a useful modality in the assessment of body composition changes in various clinical studies. However, limitations of MRI for assessment of body composition are related to its high cost and technical expertise necessary for analysis. Proper methods for measurement of body composition in specific medical situations like sarcopenia should be evaluated for determination of comparative validity and accuracy, within the context of cost-effectiveness in patient care. In conclusion, an ideal body imaging method would have a significant utility for earlier detection of nutritional risks, while overcoming the limitations of current imaging studies such as DXA, CT, and MRI.

Key Words: Nutritional assessment, Computed tomography, Sarcopenia

INTRODUCTION

Measurement of body composition is required for evaluation of nutritional status in surgical patients. Although evaluation of body weight could be an appropriate end point for

assessment of nutritional status in some circumstances, weight change may not always represent nutritional states accurately. Although there could be significant shift of body composition between lean soft tissue and fat mass due to pathologic conditions, some patients may show weight stability. Therefore, other methodologies, such as anthropometry, hydrometry, impedance, and imaging modalities, have been used to assess body composition in medical research or clinical settings. Among these tools, imaging techniques focusing on the value of lean soft tissue could be useful for prediction of nutritional state and risk assessment in some clinical scenarios. Here, we introduce imaging technologies to evaluate the nutritional state and their

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Correspondence to Hoon Hur

Department of Surgery, Ajou University School of Medicine, 164 WorldCup-ro, Yeongtong-gu, Suwon 16499, Korea
Tel: +82-31-219-5200, Fax: +82-31-219-5575, E-mail: hhcm75@naver.com

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application to special clinical situation, such as sarcopenia.

1. Why do we need imaging techniques for nutritional assessment?

Compared to the simple measurement of weight change alone, the assessment of body composition can be more important in predicting clinical outcome associated with weight loss or gain. For instance, obesity-related cardiometabolic risk is frequently assessed by calculating body mass index (BMI) or anthropometric measurements such as skinfold thickness and circumferences. However, when age, gender, and other clinical conditions are considered, obvious limitations exist with simple risk assessment using BMI or anthropometry alone. It has been well described in some medical literature that the distribution of adipose tissues in the intra-abdominal cavity is an important clinical feature in evaluating the risk for insulin resistance and associated dyslipidemia, conditions that are related to medical comorbidity^{1,2} and mortality.^{3,4}

Regarding voluntary weight loss in obese patients, the proportion of fat or lean tissue loss would be approximately 80% and 20%, respectively,⁵ and it can be associated with a number of benefits. This composition of body mass loss is influenced by numerous factors such as gender, hormonal status, physical activity, and type of weight loss intervention (dietary, pharmaceutical, or surgical). However, with involuntary weight loss during chronic disease, injury, or malignancy, there are tremendous changes in body composition that induce the serious loss of lean soft tissue, accompanied by possible preservation of adipose tissue mass.⁶ Negative energy balance in these patients with reduced physical activity (*i.e.*, patients in bed rest and physiological aging) results in accelerated loss of lean tissue greater than that of adipose tissue.⁷

Therefore, the accurate measurement of body composition between lean and adipose tissue mass and distribution of lipid burden may be important in the management of nutritional problems in patients observed in clinical practice and the measurement of outcomes in clinical research. Here, we discuss the most accurate imaging methods for use as clinical tools in the measurement of body composition and distribution.

2. Imaging techniques for body composition

1) Dual-energy x-ray absorptiometry

Dual-energy x-ray absorptiometry (DXA) is a gradually used imaging modality that measure body composition at the molecular level.⁸ Fat and fat-free soft tissue, as well as bone mineral mass, can be estimated at the whole body and regional levels using this modality.^{9,10} DXA is a fast, and non-invasive method for body composition assessment, and the radiation exposure is relatively small and safe for repeated assessments. However, measurements are affected by thickness of tissue and lean tissue hydration. Moreover, the inability of DXA to differentiate compartments within fat (visceral, subcutaneous and intramuscular) and lean soft tissues (muscle and organ) also may lead a practical weakness of this technique in clinical settings. Although some limitation exists, its cost decreases because DXA machines already have been used for the assessment of osteoporosis in many medical centers worldwide, and the role of DXA increases beyond measuring bone density only.

2) Computed tomography

Computed tomography (CT) is a gold-standard imaging method for body composition analysis at the tissue-organ level.⁸ Skeletal muscle, bone, and fat tissue as well as visceral organs have specific Hounsfield unit ranges, allowing their identification in the cross-sectional CT image.¹¹ Subsequently, the tissues area (cm²) of the cross-sectional image is calculated by multiplying the number of pixels of individual tissue. Since CT can quantify the areas of muscle by measuring a specific range of attenuation values, several previous studies characterized CT imaging as a valid and accurate method to measure body composition.¹⁰ When some conditions like elderly individuals and muscular dystrophy described muscle atrophy, the normal attenuation of muscles can be changed into fatty attenuation.^{12,13} For assessment of body composition, the landmark of cross-sectional level effectiveness in CT imaging has been the third level lumbar vertebra (L3). In a study using cross sectional image of magnetic resonance imaging (MRI), it was well described that cross-sectional area in a single image around the L3 level provides the best correlate of whole-body mus-

cle volume.¹⁴ Moreover, the image of this level can identify a composition of other specific tissues like visceral adipose tissue, subcutaneous adipose tissue and intramuscular fat tissue. Estimation of this composition using this CT image has been used to evaluate the patients' condition in the metabolic disease like a morbid obesity or diabetes mellitus.^{15,16}

The radiation generated by the CT scan is relatively high, thus it should not be considered for a measurement, which can be repeated frequently. Moreover, allowing exposure of patients to high radiation for the aim of conducting a clinical trial about body composition may be considered unethical.

However, clinical trials for assessment of body composition can be planned with CT scans when the images are obtained as a part of the medical diagnosis (*i.e.*, follow-up purposes of cancer patients).

3) Magnetic resonance imaging

An advantage of MRI over CT is that the MRI is safer in terms of radiologic exposure because it does not require ionizing radiation. Also, adipose tissue, skeletal muscle, edema, and visceral organs can be quantified using specific analyzing tools.⁸ In terms of visualization, the delineation of tissues and organs is associated with the tissue-specific magnetic resonance properties, including the density of hydrogen atoms and the longitudinal and transverse relaxation times.⁵ MRI imaging has been a useful modality in the assessment of body composition changes in clinical studies of sarcopenia,¹⁷ obesity,^{18,19} hemodialysis, and human immunodeficiency virus.²⁰ Limitations of MRI for the assess-

ment of body composition are related to its high cost and technical expertise necessary for analysis. Therefore, it would be impractical to apply MRI as a routine follow-up imaging modality when planning a large epidemiological study in a clinical setting.

3. Efficacy of imaging techniques in evaluation for sarcopenia

Sarcopenia, defined as the age-related involuntary loss of muscle mass and strength, represents a major feature of the aging process.²¹ Because several studies have suggested that sarcopenia is related to critical health-related events, including morbidity and mortality,²² sarcopenia has been considered as a matter of vigorous research. In particular, low levels of skeletal muscle cross-sectional area, density, and mass have been described to be correlated with strength deficits²³ and mobility limitation²⁴ in sarcopenia. Therefore, in groups at high risk for age-related muscle mass loss, appropriate imaging methods that have good validity, precision, and accuracy are required to identify these deficits and to monitor the potential interventions that may be part of the treatment strategy.

The main imaging techniques that are commonly used to measure skeletal muscle mass and quality are DXA, CT, and MRI. DXA has been shown to be a available method for measurement of lean body mass during aging processes; yet DXA is unable to assess fat infiltration into skeletal muscles. Although CT and MRI have been well described as useful in the detection of skeletal muscle changes, these imaging technologies are limited by factors including high operational costs. Therefore, proper methods to measure body

Table 1. Characteristics of imaging techniques for body composition

Imaging technique	Advantage	Disadvantage
Dual-energy x-ray absorptiometry	Regional measurement for each body sites. Repeat measurement due to low radiation exposure	Different operating system according to manufactures Influence of tissue thickness and hydration
Computed tomography scans	Precise quantitative measurement Regional measurement Various compositions like fatty tissue High resolution Useful in clinical setting	Specialized skills for operation Large exposure of radiation
Magnetic resonance imaging	Excellent resolution of images Most accurate composition Safe for pregnant women	Highly specialized clinical setting High cost Long time to get images

composition in sarcopenia should be evaluated for purposes of determining comparative validity and accuracy, within the context of cost-effectiveness in patient care.

CONCLUSION

An ideal body imaging method would have a significant utility for earlier detection of nutritional risks, while overcoming the limitations of current imaging studies such as DXA, CT, and MRI. We listed their advantage and disadvantage in Table 1. Also, it would be necessary for the new imaging method to be convenient, safe, and cost-effective for use in clinical practice. Recently, a moving table fat-water MRI technique is suggested as one with potential as an ideal method of measuring body composition. This MRI technique can acquire an entire noninterpolated whole body dataset, and these data can be subsequently segmented using automated analysis techniques.²⁵ It can be performed on standard 1.5 tesla and 3 tesla body imagers in 30 minutes or less.

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