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Body composition measurement using computed tomography: Does the phase of the scan matter?

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Objectives: The aim of this study was to determine, from the methodologic standpoint, the effect of the presence or absence of intravenous contrast on body composition variables obtained by analysis of computed tomography (CT) images.
Methods: Triphasic abdominal (noncontrast, arterial phase, and portovenous phase contrast) CT scans from 111 patients were analyzed by two independent assessors at the third lumbar vertebral level using SliceOmatic software (version 5.0, TomoVision, Montreal, Canada). Variables included skeletal muscle index (SMI), fat and fat-free mass (FM and FFM, respectively), and mean skeletal muscle Hounsfield units (SMHU).
Results: Mean SMHU was lowest in the noncontrast phase (29.4, standard deviation [SD] 8.9 HU), followed by arterial (32.4, SD 9.3 HU) then portovenous phases (34.9, SD 9.4 HU). The mean skeletal muscle attenuation was significantly different depending on the phase of the scan in which the images were obtained. Calculated FM was significantly lower in both arterial (28.6, SD 8.8 kg, $P < 0.0001$) and portovenous phase scans (28.5, SD 8.9 kg, $P < 0.0001$) when compared with noncontrast (29.2, SD 8.9 kg). The mean FFM was not significantly different as measured on noncontrast, arterial, or portovenous phase CT scans (48, SD 11.2; 48.1, SD 9.8; and 48.6, SD 10.2 kg, respectively). No difference was seen in SMI. Interobserver reliability was high.
Conclusions: The definition of myosteatosis should include a standardized phase of CT for analysis and this should be incorporated within its definition. However, as the magnitudes of the differences were relatively small, the effect of the phase of the scan on predicting outcome needs to be determined.

Introduction

Computed tomography (CT) analysis of body composition variables, most frequently the presence of sarcopenia and more recently myosteatosis, has gained increasing popularity in recent years, with numerous studies examining the effects of these patient factors on survival in a number of types of cancer [1,2]. An association also has been drawn between these variables and chemotherapy-related toxicity [3,4], surgical outcomes [5], and time-to-tumor progression [6]. Several different threshold values for the diagnosis of these two conditions have been

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described, and there is a lack of consistency in the literature on the optimal values for the assessment of these body composition variables [2,7,8].

There are a number of methodologic considerations necessary for the analysis of body composition using CT scans [9], including regular calibration of the CT scanner, measurement site [10], and definition of upper and lower radiodensity thresholds of various normal tissues. The initial descriptions of the analysis of body composition measures using CT suggested the analysis should be performed on contrast-enhanced rather than noncontrast CT scans [11], however, there is a lack of consistency in the more recent literature regarding the radiologic protocol of the CT scans analyzed, with some studies analyzing portovenous contrast phase images [1], others noncontrast or arterial phase, and some providing no mention [3, 4]. Estimation of hepatic fat content using contrast-enhanced and noncontrast CT scans appears to differ by the two techniques [12], with the use of contrast resulting in a lower estimation of fat volume, possibly due to the adverse accentuation of partial volume effects. However, the effects of the use of contrast on cross-sectional surface area of different tissue types have not, to our knowledge, been investigated previously. There also is evidence that administration of intravenous (IV) contrast medium results in a significant difference in body composition measures when assessed using dual-energy x-ray absorptiometry (DXA) [13].

Myosteatosis is the process of infiltration of lipid into both the inter- and intramyocellular compartments [9,14] and can be estimated by the attenuation of skeletal muscle Hounsfield units (HU) on CT scanning. The conventional lower cutoff value of normal attenuation is 30 HU, estimated to be two standard deviations (SDs) below the normal radiodensity of skeletal muscle in young, healthy adults [8,9]. The initial validation of HU threshold values for skeletal muscle were conducted in noncontrast CT scans [15], and no work has focused on the effect of contrast on these established thresholds, or indeed the effect of contrast on radiodensity, and therefore the identification of myosteatosis. In terms of HU density of other tissue types, previous work was conducted on the difference in HU values in the thorax between noncontrast and contrast-enhanced scans in the lungs and mediastinum. In this setting, the administration of contrast resulted in a significant increase in the mediastinum mean HU, a significant decrease in the mean HU in the lungs, but no appreciable difference in the soft tissue radiodensity [16].

The aim of this study was to determine the effect of the presence or absence of IV contrast, as well as the phase of contrast (arterial versus portovenous) on body composition variables obtained by analysis of CT images, focusing on skeletal muscle index (SMI), fat mass (FM), fat-free mass (FFM), and mean skeletal muscle HU (SMHU).

Methods

Patients who had undergone triple-phase abdominal CT scans (noncontrast, arterial, and portovenous phase contrast scans) at Nottingham University Hospitals NHS Trust for any indication between April 1, 2014, and September 20, 2015, were included in the study. Patients who had any suggestion of any intraabdominal fluid, which may bias the assessment of body composition variables such as those with a hemoperitoneum or ascites, were excluded from the series due to concerns that this may affect body composition measures. Scans with significant movement artifact or where the region of interest was not included on the scan also were excluded. Patient data were extracted from the electronic patient notes on gender, age, and patient demographic characteristics, particularly height and weight within 1 mo of the CT scan. Missing data on patient height and weight were obtained by review of patients' hospital care notes. The conduct of this study was approved by the Audit Department of Nottingham University Hospitals NHS Trust.

Triphasic acquisition of CT scans

Electronic copies of the three phases (noncontrast, arterial, and portovenous) of abdominal CT scan at the third lumbar vertebra (L3) were obtained in Digital Imaging and Communication in Medicine (DICOM) format from the hospital Picture Archiving and Communication System (PACS). These scans were performed for routine clinical reasons and were identified retrospectively from the Computerised Radiology Information System (CRIS v2.09, HSS, Healthcare Systems, Mansfield, UK) used by the radiology department at a single institution. During this time, two helical CT scanners in the institution were used for the acquisition of all studied DICOM images (Optima CT660, GE Healthcare, WI, USA and Ingenuity 128; Phillips Healthcare, Best, The Netherlands). These CT scanners were calibrated weekly to ensure that the standard HU values (CT number scale) measured against water (HU = zero) and air (HU = –1000) satisfies quality assurance (QA) testing (manufacturer specific). No QA testing failure event was recorded for the duration of the studied scans. Enhancement of arterial and portovenous phases was achieved by the IV (pump) administration of a fixed dose of prescribed contrast medium for adults; 100 mL of Iopamidol (Niopam 300, Bracco, Buckinghamshire, UK). All analyzed triphasic scans had consistent protocols in terms of bolus triggering and acquisition sequence (an unenhanced phase first followed by arterial at 10–20 s and finally the portovenous phase at 65 s).

Body composition analysis

The three individual images for each patient, all slices from the identical vertebral level (L3), were analyzed independently by two investigators (KR and HJE) trained in the use of SliceOmatic software (version 5.0, TomoVision, Montreal, Canada). The cross-sectional surface area of three different tissue types was calculated from the image; skeletal muscle, visceral adipose, and subcutaneous/intramuscular adipose tissue. This analysis method relies on the differing HU radiodensities of different tissue types that are well described in the literature to segment cross-sectional area, which the software automatically calculates in cm^2. Skeletal muscle radiodensity is –29 to +150 HU [15], visceral adipose tissue is –150 to –50 HU [11], and subcutaneous/intramuscular adipose tissue is –190 to –30 HU [17]. The mean HU measurement of the skeletal muscles as well as visceral and subcutaneous/intramuscular adipose tissue within the cross-section was recorded between the three phases of scan.

FM and FFM were calculated from the cross-sectional surface area of the tissue types using regression equations validated from the literature [18]:

$$\text{Total body FM (kg)} = 0.042 \times (\text{total adipose tissue area at L3 } [cm^2]) + 11.2$$
$$\text{Total body FFM (kg)} = 0.3 \times (\text{skeletal muscle area at L3 } [cm^2]) + 6.06$$

The skeletal muscle index (SMI) also was calculated as a surrogate of the presence of sarcopenia, which normalizes the cross-sectional area of skeletal muscle for patient height (cm^2/m^2).

Statistical analysis

Data were analyzed using GraphPad Prism v6.0 (GraphPad, La Jolla, California, USA) and SPSS version 22 (IBM SPSS Statistics, Armonk, New York, USA). Data were presented as mean (SD). Cross-sectional tissue surface areas, SMI, and SMHU were all compared by subtype of CT scan using the paired Student's *t* test. Interobserver reliability was assessed between individual body composition measures (SMI, FM, FFM, mean SMHU) by two independent observers using Pearson's correlation coefficient. Correlation between body composition variables by phase of CT scan was conducted and significance determined using Pearson's correlation coefficient, with linear regression analysis performed to generate indicative equations. Bland–Altman plots were constructed to examine the data for systematic error. All analyses performed were conducted using two-tailed testing and the significance level was set at $P < 0.05$.

Results

In all, 111 patients (71 men, 40 women) who had undergone triphasic abdominal CT scans between April 1, 2014, and September 20, 2015, were selected for inclusion in the study. The cohort had a mean body mass index of 28.01 kg/m^2 (SD 5.81).

Mean Skeletal Muscle HU

The overall mean SMHU was lowest in the noncontrast CT scans (29.4 HU [SD 8.9]), with a significantly higher radiodensity seen in arterial phase scans (32.4 HU [SD 9.3], $P < 0.0001$), and a