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CT assessment of nutritional status and lean body mass in gastric and esophageal cancer

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Abstract

Background: Malnutrition is common in patients with gastric and esophageal tumors, and is predominantly associated with loss of lean body mass. Adequate assessment of preoperative nutritional status is essential for prognostication and multidisciplinary treatment planning. The aim of this study was to ascertain whether anthropometric nutritional assessment correlates with computed tomography (CT) measured lean body mass in patients with gastric and/or esophageal cancer.

Methods: This was a retrospective analysis of abdominal CT images and anthropometric nutritional assessments. The anthropometric parameters of interest were weight, height, body mass index, mid-upper arm circumference, triceps skinfold thickness, mid-arm muscle circumference, and nutritional diagnosis. The lean muscle mass area was calculated from axial-view CT images of the abdomen at the level of L3 and corrected by height for calculation of the lean mass index. Values below 55.4 cm^2/m^2 for males and 38.9 cm^2/m^2 for females were defined as low lean body mass.

Results: The sample included 70 patients, of whom 67.1% were men. The mean lean body mass index assessed by computed tomography was 47.8 cm^2/m^2 (range, 29.2–78.6cm^2/m^2), with 54.3% of patients being classified as having low lean body mass. When classified by mid-arm muscle circumference, 74.2% of patients classified as undernourished had low lean body mass on CT, compared to 40.0% of patients classified as well-nourished (sensitivity 62.2%, specificity 72.4%, accuracy 66.7%).

Conclusions: A substantial portion of patients with gastric and/or esophageal cancer exhibited low lean body mass on computed tomography. Anthropometric evaluation has limited capacity to identify these patients. Among the tested anthropometric parameter, mid-arm muscle circumference showed the best agreement with CT-measured lean body mass.

Keywords: Oncology, Nutritional assessment, Computed tomography

Background

Cancer has become a global public health problem, and is currently the second leading cause of death by illness worldwide [1]. It is estimated that, between 2000 and 2020, overall cancer rates will increase by 50%, resulting in an incidence of 10 to 15 million cases [2].

In addition to the major metabolic changes triggered by the disease itself, the adverse effects of current treatment modalities can also affect the nutritional status of the patient. Surgery, radiation therapy, chemotherapy, or any combination thereof can cause a series of side effects that contribute to reduced food intake and subsequent malnutrition, including pain, constipation, nausea, vomiting, mucositis, and anorexia [3].

In patients with cancer, nutritional status should be assessed throughout the course of treatment, starting at the time of diagnosis, with the objective of ascertaining

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nutritional status and preventing deterioration of the patient's general physical condition. Nutritional assessment also identifies patients who are undernourished, which contributes to evaluation of surgical risk [4].

According to the Brazilian National Cancer Institute (INCA, 2013), approximately 40 to 80% of cancer patients are malnourished. Several factors can be involved, including low food intake, metabolic changes, physiological changes, symptoms of the disease itself, and adverse effects of treatment [4].

According to Von Meyenfeldt [5], a substantial prevalence of malnutrition (around 60–85%) is found among patients with gastric and esophageal cancer. Weight loss is reported as a common consequence in patients undergoing gastrectomy and/or esophagectomy [6]. Cancer-associated malnutrition has negative consequences, such as increased postoperative complication rates, increased risk of infection, slower wound healing, decreased treatment tolerance, decreased quality of life, and increased mortality [7].

Several methods that can be used to evaluate body composition, from conventional anthropometry using the body mass index (BMI) and skinfold thicknesses to bioimpedance and imaging methods, such as dual-energy X-ray absorptiometry (DEXA), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound, but each method has its limitations [8].

The aim of this study was to assess whether CT-evaluated lean body mass correlates with anthropometric nutritional assessment in patients undergoing surgical treatment for gastric and/or esophageal cancer.

Methods

This retrospective study was performed through a review of abdominal CT images and anthropometric nutritional assessment data collected from the charts of patients who underwent gastrectomy and esophagectomy at a cancer center in 2015. Patients whose medical records lacked anthropometric nutritional assessment data or for whom no abdominal CT scans were available were excluded from the study. This project was approved by the institutional Research Ethics Committee (decision no. 2309/16) before the start of data collection.

We retrospectively analyzed CT images obtained as part of routine preoperative evaluation, according to the protocol of the Department of Abdominal Surgery of the A.C.Camargo Cancer Center (São Paulo, Brazil). We only considered CT examinations performed until 4 months prior to surgery and the mean time between CT and surgery was 41 days. Body composition was evaluated in the OsiriX® software environment, using previously validated parameters widely used in the literature [9–11]. Nonenhanced axial CT images of the abdomen obtained at the level of the lower portion of L3 were examined. All images were reviewed by the same radiologist, who has 10 years experience in cancer imaging. To measure the surface area of lean body mass (skeletal muscles, including the psoas, paravertebral, and abdominal wall muscles), a semi-automatic method with manual correction was used as necessary (Fig. 1). A CT density of − 29 to + 150 Hounsfield units (HUs) was used to identify the skeletal muscles. The lean body mass area was corrected by height (lean mass in cm^2/height in m^2) for calculation of the lean mass index. Lean body mass was considered low when the index at the L3 level was less than 55.4 cm^2/m^2 for males and 38.9 cm^2/m^2 for females [12].

The anthropometric parameters of interest were weight, height, BMI, mid-upper arm circumference (MUAC), triceps skinfold thickness (TSF), and mid-arm muscle circumference (MAMC). MUAC and TSF measurements were obtained using a tape measure and Lange® adipometer, respectively, and used to calculate the MAMC. These measurements were classified as proposed by Frisancho [13] for patients up to 60 years of age, and as proposed by Kuczmarski et al. [14] for older patients. Weight and height measurements were used to calculate the BMI, using the formula $BMI = W / h^2$ [15]. The World Health Organization (WHO) 1995 reference values[2] were used for patients up to 60 years of age, while the Pan American Health Organization (PAHO) reference values [15] were used for older patients.

The information collected from the CT images and the electronic medical record was exported to a Microsoft Excel spreadsheet. Data were processed in the Statistical Package for the Social Sciences (SPSS) Version 2.0 software environment. For descriptive analysis, conventional measures of central tendency (mean, median, mode) and dispersion (range, variance, standard deviation, and coefficient of variation) were used, and absolute and relative frequencies were calculated. To test for correlation between variables, the chi-square and Fisher's exact test were used for frequencies of the categorical variables; Student's *t*-test for normally distributed continuous variables; and the Mann–Whitney *U* for continuous variables without a normal distribution. The level of significance was set at 5%.

Results

The sample comprised 70 patients: 18 with esophageal cancer and 52 with gastric cancer. Overall, 54 (77.1%) had received neoadjuvant chemotherapy. The mean age was 59.9 (33–82) years; 47 (67.1%) were men and 23 (32.9%) were women. The most prevalent comorbidities were hypertension (30%), smoking (30%), diabetes mellitus (15.7%), and dyslipidemia (4.3%).

The patients' current mean (SD) weight was 70.01 (15.27) kg, height was 1.66 (0.10) m, and BMI was 25.34 (4.72) kg/m^2. The mean MUAC was 29.0 (4.1) cm, with a mean adequacy of 91.9 (12.9)%. The mean TSF was

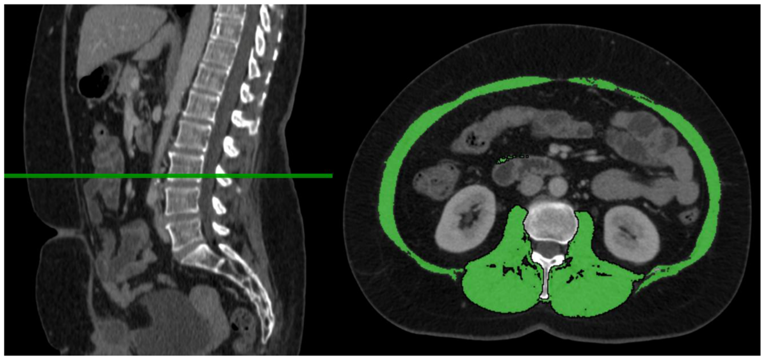

Fig. 1 Measurement of lean body mass area in an axial CT slice obtained at the L3 level

16.5 (8.6) mm, with a mean adequacy of 98.8 (45.9)%. The mean MAMC was 23.9 (3.1) cm, with a mean adequacy of 90.1 (16.3)%.

According to BMI, 8 (11.4%) patients were classified as underweight, 39 (55.7%) as having normal weight, 14 (20.0%) as overweight, and 9 (12.9%) as obese. According to MUAC, 33 (47.8%) patients were classified as malnourished, 31 (44.9%) as well-nourished, 2 (2.9%) as overweight, and 3 (4.3%) as obese. According to TSF, 31 (44.3%) patients were classified as malnourished, 13 (18.6%) as well-nourished, 5 (7.1%) as overweight, and 17 (24.3%) as obese. According to MAMC, 31 (47.0%) patients were classified as malnourished and 35 (53.0%) as well-nourished. The final nutritional diagnosis was malnutrition in 26 (37.1%), adequate nutrition in 25 (35.7%), overweight in 11 (15.7%), and obesity in 8 (11.4%).

The mean lean body mass area assessed by CT at the L3 level was 133.6 cm^2 (range, 80.4–238.1 cm^2; SD, 31.8 cm^2). The mean lean mass index was 47.8 cm^2/m^2 (range, 29.2–78.6 cm^2/m^2; SD, 8.6 cm^3/m^2). Of the 70 patients evaluated, 38 (54.3%) were classified as having low lean body mass and 32 (45.7%) as having normal lean body mass. There were weak, positive correlations between lean mass index and BMI ($r = 0.418$, $p < 0.01$), MUAC ($r = 0.325$, $p < 0.01$), and MAMC ($r = 0.409$, $p < 0.01$). There was no correlation between lean mass index and TSF.

Of the patients classified as underweight by BMI, 87.5% had low lean mass on CT; however, 50% of patients classified as well-nourished (normal weight, overweight, or obese) also had low lean mass on CT (sensitivity 18.4%, specificity 96.7%, accuracy 54.3%). When classified by MUAC, 69.7% of patients classified as undernourished and 38.9% of patients classified as well-nourished had low lean body mass on CT (sensitivity 62.2%, specificity 68.8%, accuracy 65.2%). According to TSF, 61.3% of patients classified as undernourished had low lean body mass on CT, compared to 51.4% of patients classified as well-nourished (sensitivity 51.4%, specificity 58.6%, accuracy 54.5%). When classified by MAMC, 74.2% of patients classified as undernourished and 40.0% of those classified as well-nourished had, low lean body mass on CT (sensitivity 62.2%, specificity 72.4%, accuracy 66.7%). On final nutritional diagnosis, 65.4% of patients classified as undernourished and 47.7% of those classified as well-nourished had low lean body mass on CT (sensitivity 44.7%, specificity 71.9%, accuracy 57.1%). These data are presented in detail in Table 1.

Discussion

This study found that more than half of patients with gastric and/or esophageal cancer had low lean body mass on preoperative CT. There was a weak correlation between CT-evaluated lean body mass index and the anthropometric parameters assessed (BMI, MUAC, and MAMC). Among these, MAMC yielded the best sensitivity, specificity, and accuracy for diagnosis of low body lean mass.

It is essential that the nutritional status of cancer patients be evaluated since the time of diagnosis, as undernourished patients respond poorly to therapeutic intervention and experience a higher incidence of postoperative complications, longer hospital stays, greater immune impairment, worse quality of life, and higher morbidity and mortality when compared to well-nourished cancer patients [16]. Nutritional care of these patients should be individualized throughout the treatment process, from nutritional screening through calculation of energy needs and nutritional therapy all the way to outpatient follow-up, with the aim of preventing or reversing a decline in the patient's nutritional status [5].

Anthropometry is a simple, low-cost, noninvasive method, but studies claim that databases are limited and correction factors are insufficient [17]. BMI is a well-known anthropometric parameter and is widely used in nutritional practice, but most studies state that it is highly imprecise, as it does not separate fat body mass from lean body mass, thus generalizing classification of the patient's nutritional status [5]. In addition, the proposed cutoff points for BMI commonly

Table 1 Correlation between lean body mass evaluated by CT with nutritional classification based in anthropometric data

Nutritional classification	Lean body mass evaluated by CT		Total
	Low	Normal	
Body Mass Index			
Malnutrition	7 (87.5%)	1 (12.5%)	8 (100%)
Normal	25 (64.1%)	14 (35.9%)	39 (100%)
Overweight	5 (35.7%)	9 (64.3%)	14 (100%)
Obesity	1 (11.1%)	8 (88.9%)	9 (100%)
Mid-Upper Arm Circumference			
Malnutrition	23 (69.7%)	10 (30.3%)	33 (100%)
Normal	13 (41.9%)	18 (58.1%)	31 (100%)
Overweight	0 (0.0%)	2 (100%)	2 (100%)
Obesity	1 (33.3%)	2 (66.7%)	3 (100%)
Triceps Skinfold Thickness			
Malnutrition	19 (61.3%)	12 (38.7%)	31 (100%)
Normal	8 (61.5%)	5 (38.5%)	13 (100%)
Overweight	1 (20.0%)	4 (80.0%)	5 (100%)
Obesity	9 (52.9%)	8 (47.1%)	17 (100%)
Mid-Arm Muscle Circumference			
Malnutrition	23 (74.2%)	8 (25.8%)	31 (100%)
Normal	14 (40.0%)	21 (60.0%)	35 (100%)
Final Nutritional Diagnosis			
Malnutrition	17 (65.4%)	9 (34.6%)	26 (100%)
Normal	17 (68.0%)	8 (32.0%)	25 (100%)
Overweight	3 (27.3%)	8 (72.7%)	11 (100%)
Obesity	1 (12.5%)	7 (87.5%)	8 (100%)

used in nutritional status assessment are applied across a very broad age range, and disregard gender and ethnicity [18]. According to Deurenberg-Yap et al., the relationship between BMI and body fat is significantly different across ethnic groups [19].

In the present study, BMI did not correlate well with CT evaluation of lean body mass. Fruchtenicht et al. have noted that, when applied alone, anthropometric parameters such as BMI and weight loss do not reflect an individual's actual nutritional status [15]. In another study, Duarte et al. found that BMI does not express individual body composition accurately, as it is incapable even of predicting body fat percentage and its distribution, much less quantifying lean mass [20]. Acuña et al. found a weak correlation between BMI and the Index Suggestive of Malnutrition (ISM), and concluded that BMI is not a good parameter for evaluating hospitalized adults, as a thin person may be well-nourished while an obese person may be malnourished [21]. These findings were confirmed by Thoresen et al. [22], who observed that, in a sample of 47 patients classified as having normal weight by BMI, 15 had low lean body mass and should be classified as sarcopenic.

Among the various imaging methods used to evaluate body composition, DEXA and CT stand out. DEXA is currently considered the gold standard for body composition assessment. This "scanning" technique measures the different attenuations of dual X-ray beams that pass through the patient's body, allowing segmented study of the main anatomical regions (head, trunk, and limbs) for evaluation of different body composition parameters, such as bone mass, lean mass, and fat mass. This technique is considered safe and noninvasive [18, 23]. Its major advantage is that it can be used in any age group, because radiation exposure is low. However, it is contraindicated in pregnant women. The main disadvantage of the method is that very tall or obese individuals may not fit in the scanner [24].

CT allows detailed, precise measurement of lean body mass, as well as visceral and subcutaneous fat in the abdominal region. Its advantage is that most cancer patients will undergo CT scanning anyway for disease staging and surgical planning; thus, using these scans to assess body composition avoids further exposure to ionizing radiation [24, 25]. Recently, several authors have demonstrated the association between CT-assessed low body mass and postoperative complications in patients with gastric and/or esophageal cancer [26, 27].

The present study has some limitations. Because of the retrospective design, some patients were excluded because they did not have nutritional assessment data or CT images available for analysis. Cancer staging was not included in this study due to the lack of standardized data in medical records. Furthermore, possible functional changes related to low body lean mass were not evaluated, which precluded a diagnosis of sarcopenia in this population.

Conclusion

Cancer patients should undergo evaluation of lean body mass so that the most appropriate nutritional diagnosis can be established. A substantial portion of the patients with gastric and/or esophageal cancer in our sample exhibited low lean body mass on CT, and anthropometric evaluation had limited capacity to identify these patients. The anthropometric parameter that demonstrated the best agreement with CT-measured lean body mass was the mid-arm muscle circumference, which highlights the importance of including this measurement in the nutritional evaluation of cancer patients.

Abbreviations

BMI: Body mass index; CT: Computed tomography; DEXA: Dual-energy X-ray Absorptiometry; Hus: Hounsfield units; INCA: Brazilian National Cancer Institute; ISM: Index suggestive of malnutrition; MAMC: Mid-arm muscle circumference; MRI: Magnetic resonance imaging; MUAC: Mid-upper arm circumference; PAHO: Pan American Health Organization; SPSS: Statistical Package for the Social Sciences; TSF: Triceps skinfold thickness; WHO: World Health Organization

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Availability of data and materials
The datasets analysed during the current study available from the corresponding author on reasonable request.

Authors' contributions
TMM e AGVB designed the research. ELSC e JOS performed the research. All authors analyzed the data, wrote/revised the paper. All authors read and approved the final manuscript.

Ethics approval and consent to participate
This project received approval from the institution's Research Ethics Committee (no. 2309/16).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

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